CHEMICAL WAR

REFERENCE AND TRAINING CHART

SYMBOL	NAME	COLOR & STATE LOADED	COLOR & STATE RELEASED	ODOR FIELD CONCENTRATIONS	PERSISTENCE	PRIMARY PHYSIOLOGICAL CLASS	PHYSIOLOGICAL EFFECT	PROTECTION
H	MUSTARD	HEAVY DARK, OILY LIQUID	*Liquid Slowly Vaporizes*	*Garlic Horseradish Mustard*	*Open - 1 day Woods 1 week to all winter*	*Blister Gas*	Itching, redness and blisters of skin. Injures eyes, lungs, nasal passages and throat	
L	LEWISITE	HEAVY DARK, OILY LIQUID	*Liquid Slowly Vaporizes*	*Biting Geraniums*	*Open - 1 day Woods - 1 week*	*Blister Gas*	Same as H except burns are painful	
HN	NITROGEN MUSTARDS	COLORLESS TO PALE YELLOW SOLIDS OR LIQUIDS	*Solids and Liquids slowly Vaporize*	*Fishy or soap-like to practically odorless*	*2 Hours to days*	*Blister Gas*	Same as H very injurious to the eyes	
CG	PHOSGENE	COLORLESS LIQUID	*Colorless gas*	*Musty Hay Green Corn Ensilage*	*1 to 10 minutes*	*Choking Gas*	Causes painful breathing. Injures lungs causing development of fluid in them	
DP	DIPHOSGENE	COLORLESS LIQUID	*Liquid Evaporates like water*	*Musty Hay Green Corn Ensilage*	*30 minutes*	*Choking Gas*	Same as CG	
PS	CHLORPICRIN	YELLOW OILY LIQUID	*Liquid Evaporates like water*	*Flypaper Anise*	*1 hour to 1 week*	*Choking Gas*	Coughing, crying, nausea, vomiting, and injury to the lungs	
AC	HYDROCYANIC ACID	COLORLESS LIQUID	*Liquid quickly Vaporizes*	*Bitter Almonds*	*1 to 10 minutes*	*Blood and Nerve Poison*	Causes collapse and unconsciousness from systemic poisoning	
CNS	CHLORACETOPHENONE SOLUTION	STRAW-COLORED LIQUID	*Cloud of Particles, Droplets*	*Sweetish Flypaper*	*1 hour to 1 week*	*Tear Gas*	Crying, vomiting, irritation of skin and eyes	
BBC	BROMBENZYLCYANIDE	DARK BROWN OILY LIQUID	*Liquid Slowly Vaporizes*	*Sour fruit*	*Several days (weeks in winter)*	*Tear Gas*	Crying and irritation of the skin	
DM	AD[illegible]MSITE	YELLOW GREEN GRANULAR SOLID	*Yellow Smoke*	*No odor Irritating*	*1 to 10 minutes*	*Vomiting Gas*	Headache, vomiting, sneezing and coughing	
HC	HEX[illegible]R-ET[illegible] MIXTURE	GREY SOLID	*White to grey smoke*	*Sharp-acrid*	*While burning*		Harmless	In heav[illegible] or prolonged concentration
FS	SULPHUR TRIOXIDE IN CHLOROSULFONIC ACID	CLEAR TO BROWN LIQUID	*Dense White Smoke*	*Acrid*	*5 10 minutes*		Irritates eyes and skin	
FM	TITANIUM TETRA-CHLORIDE	YELLOWISH TO BROWN LIQUID	*White Smoke*	*Acrid*	*Up to 10 minutes*		Harmless	None Needed
WP	WHITE PHOSPHORUS	PALE YELLOW SOLID	*Burns to white smoke in air*	*No appreciable odor*	*Up to 10 minutes*		Causes burns	None Available
TH	THERMATE / MAGNESIUM BOMB	DARK GREY SOLID / SILVER COLORED METAL	*White-Hot Metal* / *Burns with brilliant white light*	*Odorless*	*While burning*		Causes burns	None Available
IM NP	THICKENED GASOLINE	PALE YELLOW JELLY	*Burns with yellow smoky flame*	*Burning oil*	*While burning*		Causes burns	None Available

Artillery Shell
155 mm. holds [illegible] lbs of H
105 mm. holds 3 2 lbs of H

Mortar Shell
4.2 in holds 6 5 lbs. of H

Chemical Bomb
(all types)

Flame Thrower
holds 36 lbs.
of NP

Gas
Mask

Artillery Shell
75 mm. holds 1.3 lbs. of H

Mortar Shell
81 mm holds 4 1 lbs. WP

Airplane
Spray

Gasproof
Clothing

…FARE AGENTS

Rev. 15 Nov. 1943

FIRST AID	CLASS			USES	FIELD DECONTAMINATION
Blot off excess. Use protective ointment M4. Wash with soap and water. Irrigate eyes with water.			2 Green	[illegible]	[illegible] NC, [illegible] soapy water
Same as H except that eye ointment BAL is used in eyes instead of water.			L-GAS 2 G[illegible]	Similar to Mustard	Use sodium hydroxide or lye spray, solvents, dry mix or slurry, DANC, or hot soapy water
Same as H			HL 1 2 [illegible]	Similar to Mustard	Same as H
Rest. Maintain body temperature.			C[illegible] 1 G[illegible]	Surprise attacks on occupied targets. For quick physical effect.	Alkaline solution (e.g. GI soap in hot water)
Same as CG			D[illegible] 2 Green	Casualty and harassing effect on personnel	Same as CG
Irrigate eyes with water. Rest. Maintain body temperature.		+ CN	PS-GAS 2 Green	Harassing and casualty fire	Use solvents
Artificial respiration. Inhale amyl nitrite.			AC-GAS 1 Green	Attack on personnel in confined places	Same as CG
Irrigate eyes with water. Wash skin with soap and water.			CNS-GAS 1 Red	Counter-battery harassing fire	Strong, hot solution of sodium carbonate
Same as CNS			BBC-GAS 1 Red	To neutralize areas Counter-battery	Alcoholic sodium hydroxide spray
Sniff Chloroform		(+ CN)	DM-GAS 1 Red	Gas Cloud Attacks Mob control	None needed
None Needed			HC-SMOKE 1 Yellow	To screen operations	None needed
Irrigate eyes with water Wash skin with soap and water			FS-SMOKE 1 Yellow	For screening on broad front	Same as CG
None Needed			FM-SMOKE 1 Yellow	Screen naval operations	Same as CG
Keep burned area wet or cover with copper sulfate solution until particles of WP are picked out.			WP-SMOKE 1 Yellow	Screen enemy OP and weapons; incendiary and casualty effects	None needed
Cool molten metal with water Use dressing in first aid pack.			1 Purple TH	Destruction of structures and materiel	None needed
Use dressing in first aid pack			1 Purple IM	Destruction of structures Attack on fortified positions, tanks and vehicles	None needed

Casualty Gases — Harassing Gases — Chemical Cylinder Holds 36 lbs FS — Irritant Gas or Incendiary Grenade holds 4 oz. CN-DM — Candle holds 2 lbs. DM

Screening Smokes — Incendiaries — Land Mine holds 10.5 lbs. of H — Frangible Grenade holds approximately 1 pint of agent — Pot holds 10.7 lbs. HC

GAS WARFARE

GAS WARFARE

THE CHEMICAL WEAPON, ITS USE, AND PROTECTION AGAINST IT

BY

BRIGADIER GENERAL ALDEN H. WAITT

Chemical Warfare Service, U. S. Army

Revised edition, 1944

DUELL, SLOAN AND PEARCE
NEW YORK

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TO THE MEN OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY WHO GAVE THEIR LIVES IN THE FIRST WORLD WAR AND TO THE SONS OF M. I. T. WHO IN THIS SECOND WORLD WAR OFFER THEIR LIVES IN ORDER THAT WE MAY KEEP OUR FREEDOMS AND THE PRECIOUS LIBERTIES OF THE INDIVIDUAL WHICH ARE AGAIN IMPERILED.

A. H. W.

HOW TO TELL THE GASES

L

Grandma smelled geranium,
Started feeling kind of bum.
Sure, you guessed the trouble right—
Grandma whiffed some Lewisite.

PS

Don't you find my odor sweetish?
Said flypaper to the fly.
I smell just like chlorpicrin,
And you'll think you'd like to die.

CG

Maud Muller on a summer day,
Smelled the odor of new-mown hay.
She said to the Judge who was turning green,
"Put on your mask! That there's phosgene!"

CN

Apple blossoms, fresh and dewy?
Normandy and romance? Hooey!
For the charming fragrance then known,
Now is chloracetophenone.

H

Never take some chances if
Garlic you should strongly sniff.
Don't think Mussolini's passed,
Man, you're being mustard-gassed!

—FAIRFAX DOWNEY,
Major, Field Artillery.

PREFACE

Gas Warfare has long been a mystery to most civilians and to many soldiers. Until the present emergency there were only a handful of military gas specialists in our Army, and the rank and file knew little about this new method of warfare except drill with the gas mask and the occasional use of smoke.

An extraordinary amount of misinformation has been published about poison gas so that the citizen is completely confused as to just what to expect in a chemical war. He has begun to realize only now that it is important that he understand what poison gas is, how it may be used by an enemy, and what he should do if subjected to a gas attack. He now seeks to separate the truth from the sensational and fantastic things that have been written about the chemical weapon. He is no longer interested in the academic discussion as to whether gas warfare is humane or inhumane. He realizes how futile it is to compare relative degrees of humaneness of weapons of war, none of which are humane. He wants to win the war and if possible save his own skin also. He now wants the plain truth about this weapon.

Several excellent and authoritative treatises have been written on chemical warfare, but they were prepared for the specialist, and for the technical man, or for reference purposes. An authoritative book has long been needed which will tell the facts about chemical warfare in non-technical language. This book has that purpose. It is intended to acquaint

the average military and civilian reader with the things he needs to know about chemical warfare. It is hoped that it will prove useful to all who will be charged with taking active measures for protection in a gas attack—to the chemical officers, gas officers, and non-commissioned officers of the new Army and the air-raid wardens and anti-gas specialists of the citizens' defense corps. It should be of value to the individual soldier and citizen who may be the target of enemy gas.

A book on a technical military subject must draw its material from many sources and, in a sense, is the product of many minds. This book is no exception and the writer desires to make it clear that he appreciates his obligation. He has clothed the various thoughts in his own words and has interpreted those ideas which are not original with him in the light of twenty-five years' experience in gas warfare. He has occasionally taken issue with orthodox ideas.

Any writer on chemical warfare in this country will inevitably use as source material the splendid texts of the U. S. Army Chemical Warfare School and the Army Manuals. These books and pamphlets have been written and rewritten for the past twenty-two years, so that it is impossible to give credit to all the individuals who contributed to their growth. They were originally prepared from data contained in the A.E.F. gas manuals compiled in France in 1918, and which this writer had a small share in preparing. The A.E.F. manuals in turn derived partly from British publications. However, the officers who wrote the basic Chemical Warfare School texts are known to me, since I was secretary and instructor of the School when they were written in the early 1920's, and it is appropriate that the names of these officers be included here as follows: Colonel Hugh W. Rowan (then Captain); Colonel B. A. Brackenbury (then Major); Captain

Edward Wolesensky; Lt. Colonel Lewis S. Latimer (then Captain), and myself. Later Major William W. Wise, now deceased, Captain J. F. Smith, Colonel Owen R. Meredith (then Major) Colonel M. E. Barker (then Captain) Colonel Adrian St. John (then Captain) and Colonel John C. MacArthur (then Captain) made important additions during the early days of the school. Many others have followed and perhaps there are other pioneers whose names should be included in the foregoing. If so, the omission is not intentional.

General acknowledgment is made to the many who have assisted me in the preparation of this book. I wish each could be named. I am glad of the opportunity to make special acknowledgment to the following without whose help I could not have completed the task:

Major General and Mrs. William N. Porter, for their advice, encouragement and inspiration. General Porter, Chief of the Chemical Warfare Service preceded me at the Air Corps Tactical School, and I borrowed heavily from his ideas and phrases in the preparation of my lectures there, which served as a framework for this book.

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Colonel J. W. Rice, Colonel M. B. Chittick, Maj. G. C. Crooks, Capt. N. E. Niles, Lt. J. C. Brown, Mr. W. D. Disney and Mr. Carl Brown of the Chemical Warfare Service and Mr. Sherrill Neville of the War Department, who assisted with the illustrations, all of which are reproduced by permission of the War Department.

Major Fairfax Downey, F.A., and the *Infantry Journal* for permission to use the verse "How to Tell the Gases" by Major Downey.

My wife who read manuscript and proof and whose inspiration, encouragement and incredible patience made it possible to carry through the job of writing a book and getting it published.

It is probably unnecessary to add that although the book has been cleared for publication by the War Department the views expressed are those of the author and are not to be considered as necessarily representing official views.

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GAS WARFARE

Part One

The Poison Gases, Smokes, and Incendiaries

CAUTION

Do not rely solely on odors for the detection of gases, for the odor may be disguised or the gas odorless. ***When in doubt, put on mask!***

Observe direction of prevailing wind. Get upwind of gassed areas whenever possible.

Gases are heavier than air; stay out of low places.

FOR YOUR PROTECTION

When you detect gas, or when the gas alarm sounds, ***stop breathing.***

Dispose of arms and headgear so they do not touch ground.

Remove mask from carrier; place thumbs under lower head-harness straps; and holding facepiece with fingers extended above the eyepieces, place chin in facepiece and seat head-harness, making a comfortable, airtight seal.

Clear mask by placing hand over outlet valve and exhaling. Check Mask. ***Only then resume normal breathing.***

Examine self and equipment for traces of contamination by liquid agent.

Always test for gas before removing mask.

Do not remove mask if gas can be detected.

UNNECESSARY GAS CASUALTIES RESULT FROM:

1. Failure to put on mask at once
2. Taking mask off too soon
3. Staying unmasked in low concentrations
4. Getting caught without mask
5. Letting mask get damaged
6. Letting canister get wet
7. Taking cover in blister-gas shell holes
8. Failure to use ointment or other protection on liquid agents at once
9. Failure to protect weapons, equipment, food, water
10. Failure to decontaminate weapons or working-places (listening posts observation posts, etc.)

I

THE IDEAL WEAPON

EVERY sensible man is agreed that war should be resorted to only when all peaceful methods have failed. When in order to sustain its policies a nation has no other choice but to use force to gain its ends it should do this with as little loss as possible. Not only should there be little loss to the nation itself but unnecessary loss to its enemy should be avoided. Victory depends upon the amount of loss. The smaller the loss to both sides the greater the victory to the victor. This may be strange doctrine but it is sound. The peoples of the world are all bound together so closely today that serious loss to one affects all. We are now having daily proofs of this fact. For this reason we should understand that war is carried out not to kill or to destroy, but rather to enforce a policy, and if possible the enforcement should be accomplished without loss of honor, life, or property.

The present means of war-making are means of spilling blood and of widespread destruction. Some military scholars believe that we should replace these means by means which will terrify, which will strike at the mind and the spirit. They declare that if we can subdue the opponent without destroying him; that, if we can compel him to accept our policy without serious material loss to either of us, we shall be in a

better position at the end of a war to reap the rewards and to attain the object for which we are fighting.

Major General J. F. C. Fuller, D. S. O., formerly head of the British Army Staff College at Camberley and a vigorous proponent of the foregoing ideas, told us years ago that if we fight with the orthodox means—high explosive and cold steel—we cannot avoid causing destruction. General Fuller, who for a long time after the First World War was the lone voice crying for mechanization and modernization in the wilderness of British military orthodoxy, says in his prophetic volume, *The Reformation of War*, that the ideal weapon is one which does not necessarily destroy but which, nevertheless, is effective in subduing the opponent. He describes the characteristics of this weapon substantially as follows:

Its production should not detrimentally affect prosperity.

It should be simple to manufacture in peace or war.

Its nature should be unknown to the enemy.

It should be capable of incapacitating without killing, and the incapacity should not be permanent.

It should permit of a defense against it being well-known in advance and prepared for by the side using it.

It should inflict no permanent damage upon property.

The traditional weapons do not permit any of these characteristics being fully developed. Further, they are all based upon the idea of destruction; the destruction of men and material. General Fuller goes on to say that there is a weapon that does possess most of the qualifications—the chemical weapon. Chemical warfare has placed in our hands a military instrument which approaches the ideal more nearly than the traditional weapons. Gas, he says, should effect not only as

great a revolution in the means of making war as gunpowder but also it should effect a revolution in ideas of tactics and strategy. That it will do this in our own day is doubtful but the ability to do it exists, and sooner or later the time will come when the inherent possibilities of the chemical agent of war will be realized. From its very nature the chemical can accomplish things that the destructive weapons cannot accomplish.

The casualty results of gas warfare during the First World War were summed up in a final report made by the Surgeon General of the United States Army in 1920. It is enough to state in passing that of the 275,000 American casualties, more than one-fourth were caused by gas. Of the gas casualties only about two per cent died. Of those caused by other weapons nearly twenty-five per cent died. In other words, the man wounded by gas had about twelve times the chance to live, in comparison with his fellow soldier suffering from the effects of traditional weapons.

There is another feature peculiar to combat chemicals which is not possessed by bullets, bayonets, and explosives. It is possible to devise protection for the user of any new gas. The nature of the gas may be kept secret from an enemy so that he has no protection. Thus it may be possible to send men into battle equipped with a weapon against which the enemy has no protection while our own men are completely protected. In this case the gas need not be deadly, but merely sufficient to overcome the enemy. A powerful tear gas against which an opponent had no protection could create a tactical revolution.

The reader may feel that gas warfare is horrible and inhumane. No form of warfare is humane, for war is the

negation of humanity. New gases may cause a larger proportion of deaths and perhaps more suffering than those used in 1918, but it is unlikely that any chemical weapon will cause more terrible effects than the weapons already accepted by civilized man in war. The reader before he concludes that gas warfare is too horrible for a civilized people to tolerate, should compare gas casualties with the injuries resulting from high explosives, bullets, and bayonets. He should think of the torture that comes to the man who has been bayonetted, before death releases him, or to the man whose face has been shattered by a bullet which destroys eyes, nose, and jaw, yet fails to bring the release of death. He should also remember that most gas casualties can be avoided. Proper gas discipline and use of protective equipment can reduce to a very small percentage the number of men put out of action by chemical agents. A man in the open is helpless against the missile weapons—there is nothing he can do to avoid injury by bullets, flying pieces of metal, or shock of explosion. He can and should avoid injury by gas.

Although chemical warfare as we think of it today is the most modern of all weapons of war, with the possible exception of the tank, many attempts to develop chemical warfare have been recorded since the beginning of history.

It is interesting to note a few of the references to the direct action of chemical in past wars, for they show that the seed of chemical warfare has always been present in military thought. Only a proper combination of conditions was required to bring it to a vigorous life. The required conditions did not exist until the latter part of the nineteenth century, and the proper combination was not reached until the First World War.

The earliest recorded use of chemicals in military operations was at the siege of Plataea, 428 B.C., where the Spartans used gas as an offensive weapon against the Athenians. Wood, saturated with pitch and sulfur, was burned under the walls of the city in order to create choking and poisonous fumes to assist the assault in subduing the defenders. This first recorded use appears to have just missed success. Thucydides, the Greek historian, remarked in his *History of the Peloponnesian Wars* that the operation would have been most successful if a sudden rainstorm had not put out the fire. However, he does tell of a similar operation at the siege of Delium five years later which was a complete success. In this case the intense heat and the gases generated drove the defenders away from the city's walls in panic.

Ancient chronicles report that about the year 360 B.C. the Greeks used suffocating and incendiary mixtures formed of various chemical substances easily ignited and hard to extinguish. They consisted of pitch, sulfur, tow, and resinous wood chips. This compound was put into pots which were thrown burning from besieged towns upon the "tortoise," the shelter under which the besiegers attempted to approach the walls. Later, incendiary arrows and other incendiary devices shot from catapults came into use.

Greek fire was perhaps the most famous of all of the early means of chemical warfare. This compound was a powerful incendiary which produced suffocating fumes. Early writers state that it would ignite when brought in contact with the water and float and burn on the surface of the sea. It is said to have been invented by Kallinikos, who is described by some as a Syrian chemist who saved the Byzantine Empire from further domination by the Mohammedans, and by others, as a Greek architect who fled from Heliopolis to

Constantinople in 673 A.D. and who devised the mixture from an earlier formula about 660 A.D. The exact composition of Greek fire is not known. The process for its manufacture was kept a close secret for several hundred years. It must, however, have contained rosin, pitch, sulfur, naphtha or petroleum, quicklime and perhaps also saltpeter. It was discharged from tubes in the bows of the ships.

At the siege of Petra, in the days of the Roman Empire, the Persians used vases filled with a fire compound of sulfur, asphalt, and naphtha. These were thrown into the city by mangonels—a military engine for hurling rocks and javelins. When they broke, the compound burst into flames which could not be extinguished and which gave off choking gases.

Smoke was successfully used in a river crossing by Charles XII of Sweden in 1701. Under cover of a thick cloud produced by burning damp straw, Charles was able to cross the Dvina and take position in the face of superior forces before the enemy learned what was happening. During the Siege of Sebastopol, 1855, Admiral Lord Dundonald submitted a plan for the use of gas for the reduction of the Russian forts. His plan was to use between 400 and 500 tons of sulfur and about 2,000 tons of coke and with the first favorable and steady wind to vaporize the sulfur with the use of the coke and thus suffocate the garrison. The English government admitted the plan was feasible, but would not permit putting it into execution. The use of sulfur was suggested at the siege of Charleston in the Civil War.

As a matter of fact, modern chemical warfare might just as well have started during the War Between the States in 1862 as during the World War in 1915. Only the failure of the War Department to grasp the golden opportunity offered by a sagacious and loyal citizen of New York City, one John

W. Doughty, prevented this. Not only did Mr. Doughty recommend to the Secretary of War a practical scheme for using gas but he actually suggested the very same gas the Germans used so successfully at Ypres over fifty years later.

Mr. Doughty's letter can still be seen in the Archives Building in Washington where it is filed in the Old Records Division of the Adjutant General's Office. It was published a few years ago in the *Journal of American Military History* with interesting comment by F. Stansbury Haydon.

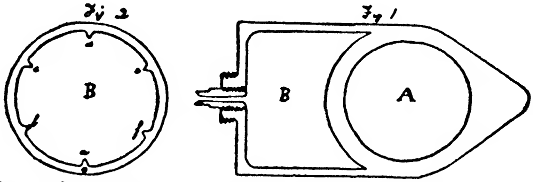


Fig. 1 Longitudinal section. Fig 2 Transverse section of chlorine chamber. The flanges a. b c d e f. are to strengthen the chamber, without much diminishing its capacity—. A. Chamber of a common shell— B Chlorine chamber. . There is no communication between the two chambers they are both in the same casting—

HON. EDWIN M. STANTON SEC. OF WAR

Sir

The above is a representation of a projectile which I have devised to be used as a means for routing an *entrenched* enemy. Believing it to be new and valuable, I send the War Department a brief description: Chlorine is a gas so irritating in its effects upon the respiratory organs, that a small quantity diffused in the atmosphere, produces incessant & uncontrollably violent coughing.—It is 2½ times heavier than the atmosphere, and when subjected to a pressure of 60 pounds to the inch, it is condensed into a liquid, its volume being reduced many hundred times. A shell holding two or three quarts, would therefore contain many cubic feet of the gas.

If the shell should explode over the heads of the enemy, the gas would, by its great specific gravity, rapidly fall to the ground: the men could not dodge it, and their first intimation of its presence would be by its inhalation, which would most effectually disqualify every man for service that was within the circle of its influence; rendering the disarming and capturing of them as certain as though both their legs were broken.

To silence an enemy's guns or drive him from his entrenchments, it would be only necessary to explode the shells over his head or on his windward side. If exploded in rapid succession over, or within a fort, evacuation or surrender could not be delayed beyond fifteen minutes. Casemates & bomb-proofs would not protect the men.

This kind of shell would, I think, in the present advanced state of military engineering, be a very efficient means for warding off the attacks of iron-clad vessels and *steam rams;* for, as to the steam ram, a ten inch gun that would carry a shell containing a gallon or two of the liquid, would with ordinary accuracy, be able at the distance of ¾ of a mile, to envelop him in an atmosphere that would cause his inmates to be more anxious about their own safety than about the destruction of their enemy.

It may be asked if the gas which drove the enemy from his guns, would not prevent the attacking party who used the gas, from taking possession of the abandoned position. I answer it would not: for, this shell does not like the Chinese stink-pots, deposite a material emitting a deleterious gas *lighter* than the atmosphere, but suddenly projects into the air, a *free* gas much *heavier* than the atmosphere, which does its work as it descends to the earth, where it is soon absorbed.

Experiment alone can determine whether this shell has any practical merit. Possibly, I overrate its value; but it must not be forrgotten [*sic*], that while it does the work of an ordinary shell, it also carries with it a force against whose effect the most skill-

ful military engineering can not possibly make any adequate provision.

As to the moral question involved in its introduction, I have, after watching the progress of events during the last eight months with reference to it, arrived at the somewhat paradoxical conclusion, that its introduction would very much lessen the sanguinary character of the battlefield, and at the same time render conflicts more decisive in their results.

If I have erred, I have, *at least* meant well.

HON. EDWIN M. STANTON *Yours,*

Respectfully,

JOHN W. DOUGHTY

April 5th/62 419 Eighth Avenue, New York

Mr. Haydon in his comments on the Doughty letter says:

Despite the practical possibilities of Doughty's plan, there is no evidence that the letter was ever answered, or that any consideration was given it. In the light of modern progress in weapons it would seem that the War Department ignored a suggestion that might have been made an important factor in the prosecution of the war. But if one considers the volume of curious suggestions and inventions that flooded the War and Navy offices, it is a wonder that Ericsson's ironclad, or Lowe's balloons ever received a hearing. What officials had to contend with is well illustrated by the letter of Joseph Lott, of Hartford, Connecticut, wherein he seriously advocated that fire-engines be run up to the Confederate works at Yorktown and Corinth to compel evacuation by spraying large quantities of chloroform on the defenders. With the Confederate garrisons thus anaesthetized, the capture of these besieged towns, wrote the well-meaning correspondent, would be a simple matter.

Prior to the Crimean War and the War Between the States the science of chemistry had not been developed to any ex-

tent. It was not until well into the nineteenth century that really great progress was made in this science.

As the development of the sciences brought forth new toxic compounds, their use in war began to receive serious thought. The fact that thought was given to the possibility of the use of poison gases is shown by the consideration given to the question in the Hague Conference of 1899. When the nations met at that conference, it was on the agenda to make a proposal to forbid the use of certain materials and devices in war. John Hay, who was our Secretary of State, counselled Admiral Mahan, our representative, at the Peace Conference, to have nothing to do with any proposal to prohibit these new methods. Concerning this proposal, Secretary Hay wrote the following:

> The expediency of restraining the inventive genius of our people in the direction of devising means of defense is by no means clear, and considering the temptations to which men and nations may be exposed in a time of conflict, it is doubtful if an international agreement to this end would prove effective. The dissent of a single powerful nation might render it altogether nugatory. The delegates are, therefore, enjoined not to give the weight of their influence to the promotion of projects the realization of which is so uncertain.

Note with what fidelity and foresight Admiral Mahan carried out Secretary Hay's instructions in his words uttered at the time the Hague Conference of 1899 adopted a resolution to forbid the use of asphyxiating gas in shells. He declared:

> 1. That no shell emitting such gases is as yet in practical use, or has undergone adequate experiment; consequently, a vote taken now would be taken in ignorance of the facts as to

whether the results would be of a decisive character, or whether injury in excess of that necessary to attain the end of warfare, the immediate disabling of the enemy, would be inflicted.

2. That the reproach of cruelty and perfidy, addressed against those supposed shells, was equally uttered formerly against firearms and torpedoes, both of which are now employed without scruple.

3. That it was illogical, and not demonstrably humane, to be tender about asphyxiating men with gas, when all were prepared to admit that it was allowable to blow the bottom out of an ironclad at midnight, throwing four or five hundred men into the sea, to be choked by water, with scarcely the remotest chance of escape. If, and when, a shell emitting asphyxiating gases alone has been successfully produced, then, and not before, men will be able to vote intelligently on the subject.

I represent a people that is animated by a lively desire to make warfare more humane, but which may nevertheless find itself forced to wage war; therefore, it is a question of not depriving itself through hastily adopted resolutions of means of which it could later avail itself with good results.

The United States of America did not sign.

It is now known that much experimental work on the poison gases was carried on until 1907 or 1908 by several nations. From that time on, apparently relying on the Hague Convention, most of the nations gave up experimental work looking to the use of chemicals for direct chemical action.

II

THE BIRTH OF CHEMICAL WARFARE—THE FIRST GAS ATTACK

WARFARE, from the Middle Ages until the First World War was a matter of cold steel or hot splinters and fast-moving metals propelled by explosive chemicals. The stalemate that was reached quickly on the Western Front in 1914 brought in trench warfare and with it a new factor to be reckoned with by the military—the direct action of chemicals as weapons.

Chemical warfare is concerned with the chemical, not as an explosive agent to propel bullets or fragments of steel, but as the active agent itself, to cause injuries by irritation, burning, or asphyxiation, to contaminate ground so that it cannot safely be occupied, to screen operations or decrease the enemy's fire power by blanketing him in smoke, and to damage enemy personnel or materiel by incendiary effect. In general, it accomplishes its mission without destruction, except when used as an incendiary. Men are put out of action and made casualties for a period of time while ground, habitations, or equipment are made unusable without being destroyed.

The adoption of chemicals as weapons was as logical as it was inevitable in a world war in which all the principal combatants were nations highly developed in science. When

the German advance was halted after the Battle of the Marne in 1914, both sides firmly entrenched themselves. A deadlock existed; neither side could gain any material advantage. Machine guns had increased fire power to such an extent that only by an impossible superiority in man power could ground be captured. The attack had failed and mobility for both the Germans and the Allies had been lost.

It became apparent that the issue could be determined only by exhaustion, and the odds were that the Germans, completely surrounded, would be exhausted first. The Germans recognized the situation and tried to find some agency to reach the enemy behind his sandbags and down in his dugouts. They looked for something which would rob the defender of the superiority which machine guns and rifles fired from behind entrenchments had given him. Thus chemical warfare was born. The gas particles that could shoot around corners and into holes were given the job of digging the defender out of the depths into which steel particles had driven him, and from which artillery shell had failed to blast him.

Being a scientific nation and leading the world in chemistry, Germany logically turned to the chemists to provide a weapon. Modern developments of war follow scientific development. Sometimes they keep step; at other times they drop behind, but regardless of the tempo inevitably they follow. Germany not only led the world in chemical development but practically controlled the chemical industry of the world. Some of her doctors of science and professors saw the possibilities of chemical warfare and brought them to the attention of the higher command. The military authorities, however, having supreme confidence in their strategical plans and military organization, in their disciplined

and trained nation, and in the vast quantities of materiel and supplies which they possessed, at first failed to see these possibilities. Only the desperate situation which faced them, when the front became stabilized and the ineffectiveness of high explosive became evident, forced a consideration and a half-hearted decision to try this new method of warfare.

The adoption of poison gas by the Germans is attributed to Professor Walther Nernst, a well-known chemist and Professor of Chemistry at the University of Berlin. As a recognition for his services to the Reich he was made a Count by Kaiser Wilhelm later in the war. Field operations in gas warfare were under the control of Professor Fritz Haber of the Kaiser Wilhelm Physical Institute at Berlin.

The first gas attack was delivered by the Germans north of Ypres on April 22, 1915, late in the afternoon, on a sector where French and British forces joined, between Bixschoote and Langemarck in Belgium. The British troops consisted of the Canadians and the British 28th Division. The French troops were the 87th Territorial and 45th Algerian Divisions, largely colored colonials. The place selected for the attack was a weak point, as is always the case where troops of different nationalities join.

The weather was perfect, a glorious spring day. During the morning there had been somewhat more than the daily artillery shelling of Ypres, but it wasn't unusual, and by noontime it had stopped. During the early part of the afternoon everything was quiet. Suddenly at 5:00 o'clock (British time), the calm of the spring afternoon was shattered as a furious bombardment of Ypres was started by the heavy guns. For the first ten minutes the German light batteries were silent and no shell fell in the forward trenches, which were about four miles north of Ypres. Nothing must disturb

the quiet air here. As the bombardment began, the men in the forward positions heard a hissing sound coming from the German trenches. At first two greenish yellow clouds appeared on each side of Langemarck, which was in possession of the French. Then these merged and a heavy cloud, almost like a wall, nearly five miles in length, stretched itself along the German trenches from Steenstraat to a point a half mile west of Poelcappelle. This wall-like cloud was perhaps as high as a man's head at first but gradually it became higher as it moved slowly toward the Allied trenches. Observers who saw it from a distance said it had the appearance of a mist "such as is seen over water meadows on a frosty night." The wind was light that afternoon—only four or five miles per hour. Gradually the cloud borne by the wind swept over the Allied lines bringing horror, confusion, and death into the ranks of some 15,000 men. The time consumed by emission of the gas was only fifteen minutes, but the poisonous cloud of chlorine hung over the Allied trenches for a much longer time and swept back into the rear areas for several miles, gradually becoming weaker. The French colonials had the worst of it, for the cylinders were all emplaced in front of them. Only a part of the 3rd Brigade on the extreme left of the Canadian division was in the main path of the gas, but the cloud swung in to the rear of the Canadians as it moved back with the wind.

The Allies were entirely unprepared for such an attack. They had information through Military Intelligence that a gas attack was coming but they did not believe it. A few days before a deserter captured near Langemarck had told the French that the Germans intended to use "tubes of asphyxiating gas placed in batteries of 20 tubes for every 40 meters along the front of the XXVI Corps (French)." The

prisoner even had in his possession a cotton pad which he said was to be dipped in chemical to counteract the effect of the gas. The Royal Flying Corps was ordered to observe the German lines to see if any special apparatus could be discovered but they found nothing suspicious and no further steps were taken. It was not until French colored troops, without their officers, began drifting back down the roads through the British area that it was realized that the greenish-yellow cloud was the gas against which they had been warned. It is sometimes difficult to convince the military man of the possibilities in new and untried methods.

The casualties were about 5,000; a large number of deaths occurred on the ground, and besides these there were many deaths in the hospitals. The Germans secured sixty guns; at that time this was a severe blow to the Allies. They also secured enormous quantities of stores. It was apparent, however, that, with the characteristic stupidity that accompanies their genius for war, the Germans did not realize the success which had been obtained through this gas attack. Had they done so they might have driven through to Calais, for a big gap was torn in the Allied line and Allied morale had been weakened seriously. Their hesitation in taking advantage of the hole which had been made in the line allowed the British High Command to bring up the 1st Canadian Brigade which was in army reserve 3 miles west of Ypres and to throw in the reserves of the 27th and 28th British Divisions. They closed the gap and never again throughout the war was it opened. General Balck, quoted in Schwarte's *Der Grosse Krieg*, in his account of the battles of Ypres excuses the German failure to follow up their attack by saying that reserves for a complete breakthrough were lacking and that the effects of the new weapon were underestimated. Humanity has been

saved on several perilous occasions by this congenital stupidity of the Hun. Perhaps it can be counted on in the future.

The Allies decided to reply to the German gas attacks, but were unable to take up the offensive use of gas until the early part of September, 1915, when a chlorine gas cloud was launched by the British at Loos. Thereafter, gas warfare continued to the end, both sides making every effort to develop greater power in their chemical attack.

All of the first gas attacks were in the form of gas clouds projected from cylinders in which the poisonous material, a true gas, was contained under pressure. Since the success of such attacks is almost entirely dependent upon the wind, the offense soon turned to the adaptation of chemical warfare to grenades and artillery shell. Later came the introduction of special chemical weapons, such as the Livens Projector and the Stokes Mortar which will be described later.

A satisfactory protection against chlorine was easily obtained and the Germans looked for another gas which would be as toxic as chlorine and more difficult to protect against. Their search yielded phosgene. It is extremely poisonous and more difficult to protect against than chlorine.

The British, warned by their Intelligence Service in midsummer of 1915 that the Germans planned to use phosgene, had several months to make preparations. They set to work to devise a new gas mask. On December 11, 1915, when the attack took place, the British were ready and the Germans had lost another opportunity to gain a decisive victory. Although the protection was adequate, phosgene proved a very efficient war gas.

The Germans introduced the use of mustard gas in the vicinity of Ypres on the night of July 12, 1917. Authorities, such as Major General Amos A. Fries, head of the Gas

Service of the American Expeditionary Forces in France and later Chief of the Chemical Warfare Service of the Army, have stated that the introduction of mustard gas changed completely the whole aspect of gas warfare and to a considerable extent the aspect of warfare of every kind. It was first used simply to produce casualties and to interfere with or break up the threatened heavy attacks by the British on the Ypres salient. It did interfere with the British plans and caused 20,000 casualties in the six weeks from July 15 to August 30, 1917.

An American medical officer in charge of a British hospital received the first consignment of these casualties. The first diagnosis had been scarlet fever. This caused sufficient consternation, which was followed by much greater anxiety when it was finally realized that a new chemical agent, which not only attacked the lungs, but a man's whole body, had been introduced into the war.

In September of that same year, the new gas was used against the French in the vicinity of Verdun. The following information from an official report indicates results: "The shells had been spread over all areas from the reserve to the front line trenches and caused 5,000 casualties in 10 to 12 days. In addition to the casualties, the physical drain on the troops through having to wear masks nearly constantly has been very great." It took the Allies one year to retaliate in kind. There is a lesson in that fact.

The Germans continued to use mustard gas to great advantage throughout the winter of 1917-1918. They fired their shell mainly to cause casualties, to break morale, and to produce delay and confusion. The full tactical value of the new weapon was in the making, however, and was finally realized in the great offensive of March, 1918, which resulted

in the serious defeat of the British 5th Army. In this offensive the Germans not only used mustard gas according to their earlier methods, to produce casualties, destroy morale, and to disorganize units, but they also fired it very effectively before and during the battle to neutralize strongly held areas, which they believed it impracticable to capture by direct assault. In neutralizing the strongly defended city of Armentières so much mustard was used that it is said to have run in the gutters like water. The Germans took Armentières with practically no losses.

The first gas attack on an American unit took place on the night of February 25, 1918, when projectors containing a mixture of phosgene and chlorpicrin were fired against the 1st Division near Seicheprey. In spite of plenty of advance notice from the British Intelligence Service, and from the noise the Germans made installing the projectors, very heavy casualties resulted. These casualties were caused by general lack of gas discipline, the principal cause for gas casualties in our army throughout the World War.

As the war continued and chemical warfare methods improved, the use of chemicals became more and more important. Soon all belligerents were using them on a large scale, and by the close of the war, no attack of importance was undertaken without considering the possibility of the use of gas. Gas warfare had proved to be an effective method of waging war. There were only 17,170 gas troops in the armies of both sides; only about 120,000 tons of chemicals were used. The results were more than a million and a quarter casualties. From these figures it can be seen that a relatively small amount of material caused a large proportion of all casualties in the World War. More than 27 out of

every 100 battle casualties in the U. S. Army were caused by gas.

Although gas had been introduced and effectively used in the World War for two years prior to the entry of the United States, and for some time war had appeared inevitable, the United States Army was totally unprepared for chemical warfare in 1917. There was no organization in the War Department responsible for the development of chemical warfare. There were not a half dozen gas masks in the United States.

On April 6, 1917, a research committee was organized under the direction of the Bureau of Mines and shortly thereafter the study of gas warfare in this country began. During the first half of 1918 there were five separate agencies of the United States Government more or less directly responsible for chemical warfare. The Bureau of Mines was charged with research and development both offensive and defensive; the Medical Department was responsible for the manufacture and supply of protective materials and for the training of personnel in gas defense; the Ordnance Department manufactured toxic gas and filled chemical shell; the Signal Corps provided gas alarms; and the Engineers had special gas troops to conduct offensive operations. Obviously, such divided responsibility for chemical warfare was not effective, so on July 1, 1918, these various activities were combined into one service, the Chemical Warfare Service, National Army. The Chemical Warfare Service was made a permanent branch of our army with the passage of the National Defense Act by Congress in 1922. Today the chemical arm is an important element of our military structure.

A question frequently asked is: "What is the international legal status of chemical warfare?" Many people seem to think

that gas has been outlawed by disarmament conferences held since the First World War. This is not the case.

Treaties are apparently no longer of consequence to some nations; but for the sake of the old-fashioned who believe there is such a thing as international honor and good faith, an unqualified statement is required covering the position of this country so far as legal restrictions on chemical warfare are concerned. *There is no treaty, to which this country is a party, in effect today with any major power which prohibits our use of gas.* Many treaties containing such provisions have been drawn up, and some of them have been signed by our representatives, but not one has been finally ratified and made effective.

In the Treaty of Peace with Germany, signed at Versailles, June 28, 1919, Article 171, provided: "The use of asphyxiating, poisonous and other gases and all analogous liquids, materials or devices being prohibited, their manufacture and importation are strictly forbidden in Germany." This provision appears to have been solely for the purpose of disarming Germany.

At the Disarmament Conference held in Washington in 1921, the use of chemical agents in warfare was given serious consideration. In one of the treaties resulting from this conference the signatory powers declared their assent to the prohibition of "asphyxiating, poisonous and other gases, and all analogous liquids, materials or devices." This treaty was signed by all of the great powers except France, but it was definitely stated in the text that it would not be effective until ratified by all of the powers. It never became effective, because of France's failure to deposit her ratification.

At the Geneva Conference in 1925, the United States delegation introduced the question of chemical warfare and

a similar prohibition to that of 1921 was drawn up. The United States, Japan, Brazil, and Argentine refused to ratify the Geneva protocol. It was signed and ratified by Germany, France, Italy, Great Britain, and the Soviet Republics. In spite of this agreement, all of these powers today have a chemical warfare service as part of their military establishments. As to the value of the gas protocol, it might be noted that both Italy and Abyssinia had signed the agreement. Ten years after signing, Italy used mustard gas on a large scale against the Abyssinians. There can be no doubt left as to the realistic sense of the Senate, which refused to ratify the protocol which had been initiated by our own delegates to the Geneva Conference.

The only effective treaty prohibiting chemical warfare to which we are a party is one signed on February 7, 1923, by Guatemala, Salvador, Honduras, Costa Rica, and the United States. Today the United States legally may employ chemicals against any of her enemies.

The most extensive use of chemicals since 1918 has been by the Japanese. In 1941 the Chinese announced that the Japs had used toxic gas on more than 800 occasions. Probably the largest use was in October, 1941, when the Japs loosed tremendous quantities of mustard and lewisite on the Chinese at Ichang with decisive results. The Japs have used gas whenever they wanted to; there is even evidence that they have used gas grenades against American troops in local actions in the South Pacific.

III

PROPERTIES OF THE AGENTS OF CHEMICAL WARFARE

IN gas warfare, the most important thing for the soldier to learn is the proper use of chemical agents on the battlefield. The factors which determine the behavior of gases in the field (and hence their tactical use) are all dependent upon the physical and chemical properties of the agents. For the noncombatant the most important thing to learn is the proper method of protection against gas. The factors which influence protective measures are also dependent on the properties of the agents.

It follows, therefore, that he who expects to deal with chemical warfare, either to use it or protect against it, should know how chemical agents behave. These chapters describe the typical chemical agents and discuss those properties which have a bearing upon their use and upon protection against them. A knowledge of chemistry is not necessary in order to understand the few rules which govern the behavior of these agents.

Most people, when the words "chemical warfare" are mentioned, immediately think "poison gas." As a matter of fact, in the Chemical Warfare Service the agents are often referred to as "gases." The term "poison gas," however, is a misnomer. Most of the chemical combat substances are

liquids and solids which are disseminated in the air by various methods. Some are contained in shells, or bombs, which explode and throw the liquid or solid agent into the air in drops or in fine particles. Some solids are vaporized by heat within a container and pass into the air as a smoke. Others, generally liquids, are carried in tanks upon airplanes and released into the air to fall to the ground as droplets or as a fine mist. A few—those which are volatile, that is, which enter readily into the gaseous state—can be released directly from cylinders, merely by opening a valve, and form a dense cloud which is carried by the wind.

Whether we call these materials chemical agents, combat chemicals, or poison gases, the terms all refer to any substance useful in war which, by its normal and direct chemical action, produces either a powerful result upon the body, a screening smoke, or an incendiary effect. Note the words "by direct chemical action." The active agent itself creates casualties directly. TNT, picric acid, smokeless powder, are all chemicals but they are useful in war because they propel shell fragments or bullets by their explosion. They exert their chemical effect indirectly and so we do not speak of them as chemical agents.

Not all agents are poisonous in effect. Some are toxic, some non-toxic. A *toxic* agent is one that is capable of destroying life or seriously endangering health when applied to the body externally, when breathed, or when taken in moderate doses internally.

The *concentration* of a chemical agent is important, for it is the concentration at a target that determines the result of a chemical attack. By concentration is meant the amount of chemical agent present in a unit volume of air. Concentration may be expressed in percentage by volume, in parts

per million, or as the weight of agent per unit volume of air. The latter expression is preferred and is given in number of ounces of agent per thousand cubic feet of air.

A *lethal* concentration is one that will kill the average unprotected man. An *intolerable* or *harassing* concentration is the quantity per unit volume of air required to cause the wearing of the gas mask, or to destroy completely the working efficiency of an unmasked man.

A *casualty* agent is one having such characteristics that a dangerous or killing concentration can be set up under battlefield conditions. Such agents are used directly against personnel for the primary purpose of producing casualties. In a word, a casualty agent is one that sends a man to the hospital.

A *harassing* agent on the other hand is one which is used primarily to force the wearing of a gas mask and in that manner delay enemy operations. Only those agents which are able to force masking with the expenditure of small amounts of ammunition are useful as harassing agents. Tear gases and irritant smokes are typical harassing agents.

Qualities of the chemical agent which give it tremendous value are its ability to shoot around corners and the fact that it is continuous in time and space. The high-explosive shell speeds on its way, reaches the target and bursts, and immediately the effect is over. The bullet speeds from the gun and, if there is no one in its way, it is useless; its effect is permanently lost. Gas, however, diffuses in the air so that it is effective over a greater space than the explosive or bullet and for longer periods of time. The effect of gas does not cease once the force which propels it is spent. While the spent bullet is dead, the gas molecule is alive and may remain alive to cause casualties hours, days, and even weeks after the combat chemical has been projected. It might be com-

pared with a machine gun able to fire millions of tiny bullets a second, each bullet drifting on after the force of discharge has been spent and each tiny casualty-producer creeping through trees and houses and wandering over walls and shelters and into dugouts.

Gas is flexible in that certain agents can be placed on the ground so that the effect will be exerted for several hours or days, or in such a way that the effect is over in a short time. Volatility has much to do with this; but, practically, the method of dispersal and the persistency of the gas are governing considerations.

Volatility may be considered as the ability of a substance to pass into a gas, or the tendency to evaporate in the open air. The volatility of a given agent is the amount of that agent held in a unit volume of saturated air. Volatility increases as the temperature increases. It is the rapidity of dispersion in air.

Just one more definition, and a most important one, which will be used frequently—PERSISTENCY. The length of time an agent will remain effective on the ground, at the point of release, is called the persistency of that agent. If, after placing an agent on the target, the concentration remaining under conditions favorable for the use of that agent is sufficiently great at the end of ten minutes to require protection of any kind, that substance is said to be a *persistent* agent. When no protection is needed at the end of ten minutes, the agent is said to be *non-persistent*. It has been found necessary to make a further classification of persistent agents by designating those which persist over ten minutes but under four or five hours as *moderately persistent*.

It is very important to know how long a substance will persist in an area. When ground has been evacuated on

account of a mustard-gas bombardment, the length of time which must pass before it can be occupied again should be known as accurately as possible. This is as important in a factory town as it is on a battlefield.

Persistency, of course, depends on several factors besides the characteristics of the agent itself. Wind, weather, nature of the ground, all play their part. The rate of evaporation of a liquid from the ground is increased by an increased wind velocity and also by increased temperatures. Mustard gas, a persistent agent, persists much longer in the woods or in calm weather than in the open or in windy weather. It persists much longer on cold ground than on hot ground.

During a cold night an area contaminated with mustard gas might be crossed with very little danger, provided the feet have proper protection, but on the following morning after the sun has warmed the ground enough vapor might be given off into the air as a result of the increased evaporation to gas severely anyone passing through the area. The nature of the ground also has something to do with persistence for the chemical agent lasts longer in dry, sandy soil than it does in muddy or swampy ground.

Most of the chemical agents have long and unwieldy names. It is necessary to have some means of referring to them readily, and so a code designation of chemical agents, consisting of two or three letters, has been devised. The letters used in this code are known as the Chemical Warfare Service *symbol.* Although the name of one of the irritant smokes is diphenylamine-chlorarsine, this smoke is referred to generally as DM. Throughout this book the symbol will be used for those agents which do not have a simple name. Detailed descriptions of the important properties of chemical agents are given in Appendix 1.

Of the many thousands of poisonous substances known to the chemist, the number that are important as agents of chemical warfare may almost be counted on the fingers. There are very good reasons why there are so few effective combat chemicals. Not only must the warfare agent have irritant or toxic properties sufficient to irritate or cause casualties in extremely low concentrations, but it must also possess suitable physical characteristics and chemical properties, and meet rigid economic standards.

To find a material that will combine *all* requirements is practically impossible. There are ten requirements which the ideal war gas must possess. To meet the ideal specifications, a chemical agent for our armed forces must be:

1. Effective in small concentrations.
2. Unreactive, and so not easily neutralized or destroyed—difficult to protect against.
3. Easily manufactured in large quantities.
4. Composed of raw materials easily procurable on the North American Continent or in the Western Hemisphere.
5. Cheap.
6. Easy to transport—compressible to a liquid.
7. Stable on storage and stable against shock of explosion.
8. Heavier than air.
9. Effective against all parts of the body—i.e., combination of lung, eye, skin, and nose irritant.
10. Odorless, tasteless, colorless—not easily detected.

All of these requirements obviously cannot be found in one chemical; they represent the ideal. Certain of them are essential. Every agent must combine at least the first five.

It is because of the necessity of meeting these require-

ments, especially the first three, that we have so few agents from which to choose.

Obviously, any agent to be useful must be effective in extremely small concentrations. It is necessary to understand how extremely small the concentrations of the really powerful chemical agents can be and still be effective. For example, one of the tear gases has a pronounced irritant effect at a concentration of eight ten-thousandths of an ounce (.0008 ounces) in a thousand cubic feet of air. Let your mind play with that figure for a moment. You could hold much more than an ounce of this material in your hand. Suppose you divided an ounce of it into 10,000 particles. Then take eight of those parts and put them in a box ten feet high, ten feet long, and ten feet wide. This almost infinitely small quantity of tear gas inside the large box would cause much discomfort if you were in it for three minutes.

According to Rudolf Hanslian, the German expert on chemical warfare, the amount of mustard gas which will produce a fatal lung casualty is between six one-thousandths (.006) and two-tenths (.2) of an ounce per thousand cubic feet of air, depending upon the time the victim is exposed. Hanslian also states that the eyes may be injured by concentrations of mustard gas as weak as one part in fourteen million (14,000,000) on long exposure. It can thus be understood that when we speak of small concentrations of chemical agents we are speaking of almost infinitesimal quantities, quantities which can be disseminated in the air with little difficulty.

The common poisons with which we are familiar would not do at all. They require too great concentrations to cause injury. Chlorine, the poison gas used in the first gas attack by the Germans, is many times less toxic than the agents which

came into use later in the World War. It takes something like five or six ounces of chlorine in a thousand cubic feet of air to cause death after ten minutes' exposure. That is a long way from the fraction of an ounce of mustard gas, 0.15 to be exact, required to produce the same effect.

The most poisonous chemical that exists is valueless in warfare unless it can be manufactured quickly and in sufficient quantity. The chemical that is effective, cheap, and easily manufactured, is of little use if protection against it is easily obtained. Consequently, one quality of the ideal chemical agent is that it must not combine readily with other substances, so that it cannot be easily destroyed or removed. An unreactive chemical is sought, since the unreactive chemicals are more likely to pass through a gas mask without being filtered out.

Stability is important. The ideal agent should be stable in storage and also stable against the shock of explosion. Even if the agent were otherwise effective, it would not be used if it had a tendency to break down into its elements after storage for several weeks or several months, or if it would break down when fired in a high-explosive shell. Lack of stability was one of several reasons why the very poisonous hydrogen cyanide, or hydrocyanic acid, proved to be a poor war gas. It was unstable in storage and also unstable to shock. Since the last war suitable means have been found of stabilizing this poisonous material.

The chemical selected must not be too corrosive or it will destroy the container and itself. Several agents, which might otherwise be desirable, have to be used in glass-lined shells or containers because of their corrosive nature. The use of special linings or special containers complicates manufacture, is expensive, slows down production.

To be used on the battlefield a gas must be heavier than air. Gases lighter than air rise and may have no effect on the man on the ground. They dissipate too rapidly. The fact that hydrogen cyanide is just a trifle lighter than air is another reason for its previous failure as a war gas.

An agent that will affect all parts of the body is far more useful than one which will affect only the lungs or the eyes or the skin. That is one reason why mustard gas is such an extremely valuable war material. If a man breathes it, he will become a dangerous casualty through the effect of the gas on his lungs. A very small amount in the air causes a powerful irritation on the eyes over a period of time. If a gas mask is worn, a man's lungs and eyes are protected. However, mustard gas is still effective even against a man wearing the gas mask, since it acts through the skin, and causes serious burns.

Finally, the ideal war gas should be odorless, tasteless, and colorless. It would thus get in its deadly effect without the victim knowing it and making an effort to protect himself. Carbon monoxide has no color, odor, or taste and it is likely that there may be other gases with ideal properties capable of military use. Although carbon monoxide is extremely poisonous, cheap, available, and stable, it is too light and can not be compressed to liquid. No method has ever been found that would permit its use in large quantities on the battlefield as a poison gas. Carbon monoxide, nevertheless, does cause deaths in battle because some of it is formed in every explosion. When a high-explosive bomb or shell bursts in an inclosed space, men who escape the effects of the blast sometimes die from the effects of the carbon monoxide produced. This, however, is an incidental effect and carbon monoxide is not considered as an agent of chemical warfare.

Chemical agents are *classified* in various ways, depending

upon who is doing the classifying, and in what phase of the subject the classifier is interested.

They may be classified according to their effect on the body, according to their use on the battlefield, according to their physical state (whether solid, liquid, or gas), and according to their persistency.

In classifying the agents according to physiological action, we divide them into:

Choking gases—lung irritants or suffocating gases.

Blister gases—skin irritants or vesicants.

Tear gases—lacrimators.

Vomiting gases—irritant smokes or sneezing gases.

In classifying according to tactical use or use on the battlefield, we have casualty, harassing, and screening agents, and incendiaries. According to persistency, we have non-persistent and persistent agents. Since the persistency of an agent has material effect upon its use, this property is indicated on all chemical munitions. Thus, one green band on a shell or bomb denotes non-persistent, while two green bands denote persistent. Moderate persistency is not indicated on munitions.

The physiological classification is the most convenient method of presenting the properties of the chemical agents and so they will be discussed here according to that classification.

It should be noted that many of the agents have secondary effects in addition to their primary action. For example,

chlorpicrin is classified as a suffocating gas because its primary action is to attack the breathing apparatus. However, chlorpicrin is a very powerful tear gas. It might well be included in the list of tear gases. Mustard gas is classified as blister gas or a skin irritant since most mustard-gas casualties are caused by the action of the liquid or vapor on the skin. Mustard gas, however, if breathed, is a powerful lung irritant, and if the vapor comes in contact with the eyes, it acts as a tear gas. In studying the agents they are classified in the group in which their principal action places them, and so chlorpicrin will be described under the lung irritants and mustard gas under the skin irritants.

Chemical agents produce results under field conditions which depend upon a number of factors that frequently are hard to estimate accurately. The quantity of agent used, the weapon in which used, the area covered, the weather conditions, protection available, gas discipline, and physical condition of the men, are all important factors which must be considered.

It is important to know that the effect of a chemical agent is, in general, directly proportional to the concentration and the time of exposure. What this means is that if it requires a certain amount of gas to disable a man in five minutes, it will take only about half that amount if he is exposed for a period of ten minutes.

The relation may be expressed by the formula: $C \times T = K$, where C represents concentration, T represents time, and K represents a constant for any given effect. There is a slight increase in this constant K with time of exposure, but within reasonable limits this can be disregarded.

The important point that should be noted is that while concentration is a vital factor in causing casualties, time of

exposure to that concentration is equally important. Thus if you breathe for a very short time a light concentration of a gas, such as phosgene or chlorine, which is not sufficiently strong to cause coughing or irritation you may come to no harm at all; whereas, if you remain in this light concentration and breathe the gas for a relatively long period, you are very likely—in fact, almost certain—to become a severe casualty. In other words, you should put on your gas mask at the slightest suspicion of gas. Considering the persistent gases, such as mustard gas, where exposure may last for hours, it can be understood that a very small concentration (C) of mustard gas will suffice to cause a casualty, since the time (T) factor is so large.

In describing the chemical warfare agents, I have selected one agent in each classification for special attention and emphasis; that is, a *type agent* has been selected to represent each class. If the reader thoroughly understands the prop-

Physiological Action	Name	Symbol	Tactical Use
Vesicants — blister gases	Mustard Gas	(H)	(Persistent casualty)
Lung Irritants — choking gases..	Phosgene	(CG)	(Non-persistent casualty)
Lacrimators — tear gases	Tear Gas Solution	(CNS)	(Semi-persistent harassing)
Irritant Smokes..	Adamsite	(DM)	(Non-persistent harassing)
Solid Smokes....	White Phosphorus	(WP)	(Screening agent)
Liquid Smokes ..	Smoke or FS	(FS)	(Screening agent)

erties of the typical agent of a certain classification, he can readily recognize the properties, uses, possibilities, and limitations of other agents in that class.

The table on opposite page shows the agent considered as typical of each class.

Many of the symbols used in chemical warfare were changed in August, 1943, so that British and American usage would be uniform. All the symbols used in this book are the new symbols. Readers who are familiar with the symbols formerly used by the Chemical Warfare Service should refer to Appendix 10, where both the old and the new symbols are given side by side.

◇ IV ◇

THE CHOKING OR SUFFOCATING GASES

A CHOKING gas or lung irritant is a chemical agent which, when breathed, causes irritation and inflammation of the breathing apparatus. Nearly all chemical agents irritate the lungs under some conditions, when breathed. Under field conditions, however, only those substances are useful as lung irritants which have properties that permit the sudden generation in the air of high concentrations.

Obviously, if an agent is to be effective as a suffocating gas, it must be breathed. It is assumed that any opponent will have a gas mask. Consequently, to produce casualties by the lung irritant it is necessary to obtain surprise and get enough of the agent into the air so that the enemy soldier will fill his lungs with the gas-laden air before he can put on his gas mask. This requires that the agent used be very volatile (that it evaporate quickly and that the air hold a large amount of it as a vapor). In the case of a gas that is slow to evaporate a man to be affected would have to breathe the gas-laden air for a long time. Naturally, if he has been properly trained, he will put his gas mask on at the first suspicion of a gas attack. In order to get enough gas into the air so that one or two breaths will cause a casualty, the weapon dispersing non-persistents must be able to deliver a very heavy concentration in a short time. It will be brought

out in later chapters that special chemical warfare weapons are necessary if non-persistent lung irritants are to be successfully used on the battlefield.

Phosgene (CG) is the type agent of the choking gases. Its chemical name is carbonyl chloride; its chemical formula is $COCl_2$. The name, phosgene, is derived from Greek words meaning generated by light. Phosgene is formed when carbon monoxide and chlorine are united under the influence of sunlight or when passed over hot charcoal. It was first prepared by John Davy in 1811 by exposing equal quantities of carbon monoxide and chlorine to sunlight. It is used in industry in the manufacture of dyes. This gas therefore was not new when it was first used as a chemical warfare agent by the Germans in a cloud gas attack on the British in December, 1915. It was first fired in artillery shells by the French in February, 1916, and its use in German shell was first noted in November, 1916; it was used in increasing amounts in artillery shells from that time until the end of the war. It is still an important combat chemical. Its symbol, CG, derives from the name given phosgene by the French, Collongite. This was a code designation based on the name of the place in France where large quantities of phosgene were made.

Phosgene is very effective even in low concentrations which can be easily obtained in the field. It is extremely dangerous because when breathed in low concentrations it may not be immediately severely irritating. Frequently, unless a man has breathed a large amount, the effects may be delayed for several hours or even a day. The symptoms of phosgene poisoning are first coughing and choking. This is followed by an inability to expand the chest, hurried and shallow breathing, and sometimes vomiting. Next there is

severe pain in the chest, and finally there is blueness of the lips (cyanosis) with either a red bloated face (venous congestion) or with face of grayish color indicating failing circulation.

Phosgene irritates the nose and throat only slightly and for this reason men are likely to inhale it more deeply than they would similar concentrations of some more irritant gas such as chlorine. Consequently, men gassed with CG frequently have very little warning that they have been severely affected until it is too late to avoid the danger.

The effect of the gas is cumulative; exposure to even low concentrations over a long period of time may cause severe casualties. A phosgene casualty is very similar to a case of pneumonia and in fact the effect might be called a chemical pneumonia.

The insidious nature of phosgene must be understood, since it is not unusual for a man to be seriously gassed without knowing it until too late, and because the delayed effect frequently is responsible for failure to provide the proper treatment. It is the rule that a man suspected of having breathed phosgene should be treated as a serious casualty until at least twenty-four hours have passed. As an example of the delayed action following breathing of a high concentration of phosgene, the following extract from the British *Official History of the War (1914-1918)*, may be cited:

February 3, 1917: A chemist was working on a new chemical product. A syphon of phosgene, required for the synthesis of this substance, burst on his table at 1:00 p. m. A yellowish cloud was seen by a second person in the room to go up close to the chemist's face, who exclaimed, "I am gassed," and both hurried out of the room. Outside, the patient sat down on a chair, looking pale and coughing slightly.

2:30 p. m.: In bed at hospital, to which he had been taken in a car, having been kept at rest since the accident. Hardly coughing at all; pulse normal. No distress or anxiety and talking freely to friends for over an hour. During this time he was so well that the medical officer was not even asked to see the patient upon admission to the hospital.

5:30 p. m.: Coughing, with frothy expectoration, commenced, and the patient was noticed to become bluish about the lips. His condition now rapidly deteriorated. Every fit of coughing brought up large quantities of clear, yellowish frothy fluid, of which about 80 ounces were expectorated in one and a half hours. His face became of a grey, ashen colour, never purple, though the pulse remained fairly strong. He died at 6:50 p. m. without any great struggle for breath. The symptoms of irritation were very slight at the onset; there was then a delay of at least four hours, and the final development of serious oedema up to death took little more than an hour, though the patient was continually rested in bed.

Emphasis on the delayed effect of phosgene should not lead one to believe that its action is normally slow when high concentrations are breathed. Generally under such conditions the effect is immediate and the man becomes a serious casualty at once.

Pure phosgene is a clear, colorless liquid at low temperatures. It boils at the temperature of a moderately cold November day. Consequently, if released in warm weather it would exist in the form of a gas. It freezes only at an extremely low temperature. The commercial product used in warfare is yellow or light orange colored in the liquid form, due to the presence of certain iron compounds as impurities. In the field, however, the gas cloud would have no color and if seen at all would appear as a mist or fog.

The odor of phosgene is very characteristic and once it has been recognized, it will never be forgotten. It is difficult to describe an odor for another person, but the usual description of the odor of phosgene compares it to the odor of musty hay or of green corn. Some say it smells like new-mown hay. There is also present the suggestion of acid; the individual may note a sour taste in his mouth if he breathes much of it.

Phosgene vapor is more than three times heavier than air. A cloud of phosgene, unless it is carried upward by the wind or air currents, will remain near the ground until it is much diluted. This is a great advantage in warfare because the heavy gas will flow into ravines, trenches, and dugouts, places where men normally seek refuge against bullets and explosives.

Because phosgene is a gas, except in cold weather (below 47° F.), it is non-persistent and is dissipated rapidly by the wind. In winter weather it will have somewhat greater persistency than in warm weather, but even at low temperature it evaporates rather rapidly. Phosgene is a relatively stable compound under normal conditions. It combines rapidly with water, forming hydrochloric acid and carbon dioxide. Since there is always some moisture in the air, small amounts of acid are apt to be present whenever phosgene is present in the air and, consequently, air containing phosgene will have a somewhat corrosive effect on metals. Since phosgene is rapidly changed (hydrolyzed) in contact with water, it is apparent that this agent cannot be used effectively in rainy weather. Light mist would have no unfavorable action but a heavy rain would destroy the gas very quickly and prevent it from accomplishing its purpose of causing casualties. Dry phosgene can be stored in steel containers indefinitely but

the presence of any moisture will cause corrosion of the containers.

The agent combines vigorously with alkalies. A mixture of sodium hydroxide (soda-lye) and calcium oxide (lime) absorbs phosgene. This mixture called soda lime was used in the gas-mask canister as a phosgene absorbent.

Phosgene is a gas with which the soldier can take no chances. Too much emphasis can not be given to its insidious nature and dangerous properties. If the odor of CG is detected there is only one thing to do and that is stop breathing until the gas mask has been carefully adjusted. One good breath of the gas can cause a serious casualty.

Tucked away in some World War files I found not long ago a copy of a memorandum sent on September 20, 1918, to my chief concerning a phosgene attack on one of the regiments of the division of which I was division gas officer. It was supplementary to a detailed report previously submitted which I also located in the same file. Except for changes in the names of the participants the memorandum is as follows:

1. Capt. Thomas G. McAndrews, commanding Co H, in a letter to his regimental commander, states that Pvt. Michael Cornish refused to put his respirator on until threatened with a pistol in the hands of Sergt. Martin, Bn Gas N.C.O.

2. Pvts. Smith, Presser, and Riley (listed as casualties in previous report) removed their masks before the command was given to remove them.

3. Pvt. Michael Cornish has died as a result of gassing.

Paragraph 3 speaks for itself.

Although phosgene is the type agent of the lung irritants, there are several other lung irritants which have proved effective and which may be encountered on the battlefield.

Chlorine, the first gas to be used in modern chemical warfare is not likely to be met alone because it is so active chemically that protection against it can be improvised very easily and because other more toxic agents can be provided without difficulty. However, it may be mixed with phosgene in gas cylinders where its extremely high gas pressure and the fact that it is a gas even at low temperatures make it useful in providing the necessary pressure to force the more poisonous phosgene out of the cylinders.

Chlorine is an element which plays a very important part in chemical warfare since, either in a free or combined condition, it enters, somewhere, into the manufacture of practically all other chemical warfare agents. It is a heavy greenish-yellow gas which has a pungent, disagreeable odor and a very irritating effect upon the membranes of the upper air passages. It causes violent coughing immediately if small amounts are breathed. It is two and a half times as heavy as air. It is a gas at all temperatures that would obtain on the battlefield. It dissolves readily in water. It is extremely active chemically and combines with all the metals and with most all of the other elements. It is, therefore, extremely corrosive unless absolutely dry. When chlorine is thoroughly dry it may be stored in steel cylinders indefinitely. Chlorine is used in the manufacture of mustard gas, Lewisite, phosgene, and most other chemical agents. Chlorine compounds are important in protection against gas since certain of them, for example, chloride of lime (bleach), are used to destroy mustard gas.

One of the most effective choking gases used in the First World War was diphosgene. This substance not only is as poisonous as phosgene but has a marked tear-gas effect. Rus-

sian and German authorities state that it is more toxic than phosgene. The Germans used diphosgene in shells marked with a green cross and, hence, it was sometimes known as "green cross," although the official German name for the agent was perstoff. The British who also used it called it superpalite or diphosgene, and the French called it surpalite. It has a very imposing chemical name, trichlormethylchlorformate. It is a colorless, oily liquid with a peculiar odor. It breaks down under certain conditions to form two molecules of phosgene, which is the reason for its name. Except for the fact that it is a liquid under all field conditions and has an intense tear-gas effect, it can be thought of as very similar to phosgene, and no further description of it is needed here. It is an agent which is quite likely to be used whenever lung irritants are used. It would probably be employed in shells or bombs.

Although diphosgene must be classified as persistent, since it will remain at the point of release over ten minutes, it dissipates in the open in the summer in about fifteen minutes and in cooler weather within a half hour, so it is only very moderately persistent. It has not been used by our Army although it offers some advantages over the standard lung irritant, phosgene.

Another important lung irritant is chlorpicrin (PS), which also is an effective tear gas. PS is much more persistent than phosgene and is also less poisonous. It is classified as a moderately persistent agent since it has a persistency of about an hour in the summer in open country and twelve hours in the winter. The chemical name of chlorpicrin is trichlornitromethane or nitrochloroform. It gets the name of chlorpicrin because it is made commercially by the action of

chlorine on picric acid. The symbol PS comes from Port Sunlight where the British first investigated the compound. It is a nearly colorless liquid which has a sweetish odor. Official manuals which seem to run to weird comparisons in describing chemical agents suggest its odor resembles that of sticky fly paper. The effect on the eyes is so powerful that it is felt before it is smelt. It is a very stable compound and, therefore, rather difficult to protect against, since other substances do not react with it easily; hence, it is difficult to destroy. It is taken up (adsorbed) by the charcoal in the gas mask. Its use in the future will probably be influenced by the fact that a first-class gas mask is required for protection against it. An inferior gas mask will not stand up long against strong concentrations of PS. However, other factors which might affect its use are its moderate persistency which makes it useful for harassing as well as casualty effect, and its combined lung-irritant and tear-gas effect, and the ease with which it can be loaded into shells and bombs.

The choking gases have been overshadowed greatly by the success of the blister gases. They are nevertheless of great importance and represent a serious threat at all times. I know of no projector or cylinder attacks with phosgene or diphosgene during the First World War which did not yield results sufficiently worth while to justify the time, effort, and expenditure of supplies. Casualties that occur from such attacks are sure to be serious ones. The best gas mask and the best training methods and discipline are needed to assure safety from an attack that is intelligently carried out with choking gas.

V

THE BLISTER GASES

THE most effective of all the poison gases during the First World War was a liquid which blistered the skin, burned the eyes and lungs, and went under the name of "mustard" gas. Some say the name Hot Stuff, given it by British soldiers, supplied the symbol HS by which it was once known. Indeed it is hot stuff. Mustard gas is still the standard with which other gases are compared and is the typical blister gas or vesicant. The blister gases are those combat chemicals which are absorbed in any part of the body and which cause severe blistering of the part affected.

During the First World War mustard became the most important of all chemical agents, because of the difficulty of providing protection against it. The choking gases seriously affect only the lungs. The tear gases are principally effective against the eyes. The gas mask gives complete protection against both of these types of agents. The blister gases, however, attack any part of the body with which the liquid or vapor comes in contact. Consequently, only partial protection is provided by a gas mask. There is no immediate pain resulting from contact with the vesicant and it takes some time for casualties to develop. It is difficult to protect against this insidious action.

In modern warfare, because of the blister gases, we must

provide means of keeping the gas from the entire body or keep the combatants away from the vesicant. Of the various parts of the body, the eye is the most easily affected by vesicants and, consequently, eye symptoms are the first to be noticed. A very low concentration, barely detected by the sense of smell, will cause eye burns after exposures of an hour. The lungs are the next parts of the body to be affected; next are those where perspiration occurs most frequently. Finally, if the body is exposed sufficiently long to the vapor, burns develop on other surfaces. If liquid comes in contact with any part, a burn is certain to develop.

The blister gases are all characterized by rather slow action on the body. Mustard (H) vapor takes several hours to produce a burn; Lewisite (L), another important blister gas, one-half to two hours. There is, of course, both advantage and disadvantage in this slow physiological action.

The persistent vesicant agent is extremely valuable for contaminating ground that we do not wish to occupy ourselves; that is, men do not have to be on the target when the agent is fired. It clings to vegetation. Thus when soldiers come up later, even hours after it has been fired, they may brush against the leaves of the trees, against the grass, or undergrowth, and become casualties by contact with the liquid which brushes off against their bodies, or on their clothes.

It can readily be seen how important this quality is and how it affects the use of persistent agents on the battlefield. In a retreat, for example, a persistent vesicant may be used as a barrier over which a pursuer may pass only at the risk of serious casualties. No other weapon possesses this quality.

The Germans introduced mustard gas on July 12, 1917, when they fired shells, marked with a yellow cross, against

the British Army near Ypres. A little over a week later the first large-scale use was made against the British at Nieuport, France, resulting in over 14,000 casualties, 500 of whom died within three weeks. The next month the Germans fired 100,000 mustard shells against the French Second Army and produced 20,000 casualties. The Allies did not use mustard until November, 1917, at Cambrai, and they were able to do this only because the British had captured a large stock of German yellow cross shells. It took nearly a year for them to reach large-scale production on their own account.

Ulrich Müller in *Die Chemische Waffe im Weltkrieg und Jetzt*, an authoritative German text on chemical warfare, has this to say of the importance of mustard gas to the German army: "The German front would never have succeeded in withstanding the powerful onslaught of the concentrated forces and war materials of almost the whole world if German chemists had not at that moment held the protecting shield of the Yellow Cross Substance [mustard gas] before the German soldiers."

Mustard gas (H) is known chemically as dichlorethylsulfide; its formula is $(ClC_2H_4)_2S$. It has no relation to mustard or mustard oil, although it does resemble natural mustard oil in its blistering properties and sharp, pungent odor, which may be the reason for its name given it by the British. Mustard gas was known for many years before it was first used in war. The first reference to the compound apparently was in 1854, and its very serious effect on the skin was described in technical journals a few years later. Description of the agent and of its extremely dangerous action on the body appeared in scientific publications occasionally up until the First World War. It was, therefore, not an unknown compound before this time and, in fact, there is much evidence that

before the Germans actually fired it against them in 1917, the British as well as the French had considered and abandoned its use in the belief that it would not be sufficiently effective.

J. B. S. Haldane, in his fascinating little booklet, *Callinicus: A Defense of Chemical Warfare,* tells how a British chemist suggested the use of dichlorethyl sulfide to a general in 1915. The story is so likely that it ought to be true. "Does it kill?" asked the general. No, he was told, "but it will disable enormous numbers of the enemy temporarily." "That's no good to us," the general is reported to have replied. "We want something that will kill." Doctor Haldane comments, "It is interesting to find how completely the ideas of this worthy soldier as to the object of war coincide with those of the average intelligent child of five years. I may remind you that Clausewitz held the view that the object of war was to impose one's will upon the enemy."

The French name for mustard, Yperite, came from the town of Ypres where it was first used. The Germans called it "Lost" or "Yellow Cross." The word "Lost" combines the first two letters of the names of the two chemists who devised its German manufacturing process, Lommel and Steinkopf.

The materials going into the making of mustard are cheap and readily available in this country and, although the process requires careful control and skilled operation, manufacture is not complicated or difficult. The reader with technical curiosity may be interested to know that mustard is made by the action of hydrochloric acid on thiodiglycol, and also by bubbling ethylene through sulfur monochloride.

Mustard gas not only affects the skin but is also a powerful lung irritant. It attacks the whole breathing apparatus caus-

ing inflammation of the bronchial tubes with destruction of the mucous lining and the development of severe bronchial pneumonia.

HS is very effective in extremely low concentrations. The fatal dose to the lungs is between .006 and .2 of an ounce per thousand cubic feet of air, depending on the time the victim is exposed. The eyes may be affected on long exposure by concentrations as low as one part in 14,000,000. In the case of mustard gas—and this is true of all persistent agents—exposure to a small concentration over a long period of time will cause severe injury.

In this respect mustard gas is particularly dangerous because after breathing a low concentration for two or three minutes a man loses his ability to distinguish its odor due to its effect on the nerves connected with the sense of smell. The odor of mustard gas can be detected by one who has just come into the contaminated atmosphere in concentrations as low as one part in ten million parts of air. Burns have been caused by sitting on ground contaminated with such small traces of mustard gas that no odor was observed.

During 1918, in France, a number of gassed men were being removed from the front to a hospital in the rear. At the station where the hospital train picked them up, their equipment had been dumped on the platform. A medical officer noticed a pair of field glasses in a leather case on the edge of the pile of equipment. The case bore the name of an officer. This officer's name was also on the list of gassed cases being evacuated. Thinking it too bad that the officer should lose such valuable glasses, the doctor picked them up and took them into his compartment on the train, hung them on the wall, and then lay down to sleep. The next morning he was a mustard-gas casualty himself. There was only a drop

or two of mustard on the leather case which held the glasses, but it was enough to vaporize in the air of the closed compartment, and over the period of six or seven hours cause severe eye burns which put the medical officer out of action for several weeks. Many similar instances can be cited. A little mustard gas over a long period can cause much damage.

Although the burns produced by mustard are likely to hospitalize a patient for several weeks, the deaths from mustard gas in the past were few, occurring principally in those who had breathed appreciable quantities of the vapor. Mustard gas was, without question, the most effective chemical agent used during the World War and, therefore, was one of the most potent of all weapons. About three-fourths of all the gas casualties in our army were caused by this agent. New methods of use make it even more powerful today.

In addition to being one of the most poisonous of the agents mustard gas is one of the most persistent. In summer in the open it persists from two to five days and in wooded areas a week or more. In the winter it will persist several weeks.

H is a heavy oily liquid, practically colorless and with little odor in the pure state. The impure mustard gas used in war is dark-colored, and in low concentrations has an odor which is described as that of garlic or onions. In high concentrations the odor becomes decidedly pungent and irritating. One must describe the odor for himself, however, after actually smelling it, for noses disagree. To me, its odor resembles that of horse radish rather than that of garlic or onions or mustard. The odor, however, is so characteristic that it is easily remembered. Once you have recognized it you will probably never forget it.

Below 57° F. pure mustard freezes. Consequently in cold

weather its use is limited unless it is mixed with some other compound such as chlorpicrin, which dissolves it readily. The plant product used in war is about 70% pure and freezes about 46° F. Carbon tetrachloride (pyrene), chlorbenzene, and carbon disulfide are solvents which have been added to mustard gas because they lower the freezing point and keep it in a liquid state in cold weather, and even in warm weather make the mustard more easily dispersed.

Mustard gas dissolves in most of the hydrocarbons, such as gasoline and kerosene, a fact which is useful to know in case one has been splashed with mustard gas. Kerosene is an excellent material to use in removing mustard from skin or clothes. Mustard penetrates rubber boots or clothes rapidly and so such materials do not furnish protection against liquid mustard for any long period of time.

Mustard boils at a very high temperature. Its tendency to go into the vapor state is low but only very little of it is needed in the air to be effective.

It is a very stable compound, may be stored for long periods of time, and may be fired in shells containing much explosive without being destroyed by the shock of explosion. The Germans made use of this fact during the last months of the First World War by placing a heavy charge of explosive in their mustard-gas shell. This gave them the added chance of casualties from the burst of the shell and also made it more difficult to recognize the shells as gas shells. In those days when shells burst with a small explosion it generally meant gas and the soldier was trained to put his mask on immediately without waiting to detect the odor of gas. These high-explosive mustard shells were equipped with time fuses set to burst about twenty-five feet above the ground. Thus the mustard was distributed more effectively over the

ground and an immediate high vapor concentration was produced in the air. Less gas was lost in the ground and there was more chance of direct contamination of men by the spray at the time of burst. In my opinion a shell or bomb with proper air burst should prove most effective.

H is not soluble in water and combines with water very slowly in the field. Consequently, although mustard gas which is scattered on the ground is eventually made harmless by the action of rain, this generally takes several hours and the mustard will remain effective several days unless rains are fairly heavy and continuous. In other words, a light rain or mist for a short time would have very little effect on a mustard-gas attack.

Certain compounds of chlorine combine violently with mustard and the product of the reaction is harmless. For this reason, such compounds can be used to destroy mustard gas. The reaction between mustard and chloride of lime is so violent that caution must be exercised when using dry chloride of lime to destroy mustard gas. If the dry material comes in contact with liquid mustard, so much heat is evolved that a red flame results. The heat will cause some of the unaffected mustard to vaporize. The presence of this mustard vapor in the air will cause casualties if it blows on unprotected men in the vicinity. Strong soaps will destroy weak concentrations of mustard gas.

Shortly before the end of the First World War there was ready for shipment to France a supply of a vesicant agent which was believed to be superior to mustard gas. This agent, known as Lewisite (L), was first made by Capt. W. Lee Lewis of the CWS in 1917. A plant for its manufacture was constructed at Willoughby, Ohio, and a quantity was manu-

factured. This plant was called The Mousetrap because the product was so secret that the men who were engaged in making the first lots could not leave the premises. A heavy wire fence was built around the Willoughby plant and armed guards patrolled the area day and night. The Armistice took place before shipment of this first supply could leave port, and it was sunk at sea soon after the Armistice in order to destroy the gas.

Lewisite is somewhat heavier than mustard gas, is much more irritating and more toxic, and is fairly persistent. It is an arsenic compound with the impressive name beta-chlorvinyldichlorarsine. When absorbed in the skin, it not only burns but poisons the body and will cause death if a sufficient amount is absorbed. If the vapor is breathed, the effect is severe but the effectiveness of the vapor for producing skin burns is questioned. Lewisite received much publicity in the months immediately following the Armistice. It was called the Dew of Death, because of the claim that two or three drops of the liquid on a man's skin would kill him. This claim is not greatly exaggerated, for the experiments that have been made indicate that absorption of L in the skin can be fatal. While mustard gas causes many casualties but relatively few deaths, it would be expected that a larger proportion of deaths would result from Lewisite. Lewisite has an advantage over mustard gas in that it freezes at a much lower temperature, is more volatile—and can be used in colder weather. Its chief use is in airplane spray.

Its principal disadvantage lies in the fact that it combines readily with water to form a solid compound and that the vapor is of doubtful value for causing skin burns. Although this solid is poisonous and will blister the body when contact is made, it has no vapor effect and of course intimate contact

is not likely to be made with a solid material. Humid climates would reduce the effective use of Lewisite. The odor of L is very distinctive, resembling geraniums.

Another substance which may be classed with the vesicants is the agent called "dick" by the Germans, who used large quantities of it as a filler for their yellow cross 1 and green cross 3 artillery shells in 1918. In our Army it is known as ED, but it has never been used or produced on a large scale. Its chemical name is ethyldichlorarsine. A somewhat oily liquid with a biting fruity odor, it evaporates much more rapidly than either mustard or Lewisite, and, therefore, is of moderate persistency. It is not especially irritant for the skin except when the liquid comes in contact for several minutes. It has considerable effect as a lung irritant, and it might be classed with the choking gases. Its principal value lies in its use in offensive situations where H cannot be used because friendly troops might wish to occupy ground a few hours after it is fired. In such a case if H were used, these troops would be in danger of being affected by their own gas. In the case of ED the agent would disappear before the friendly troops arrived, but would remain sufficiently long to cause casualties and interfere with enemy activity in the area.

Other agents which might be classed as vesicants are MD, methyldichlorarsine, which was studied during World War I by Germans and Americans but which was not used, and the German *bromlost*, dibromethyl sulfide, a compound similar to mustard gas except that bromine was used in place of chlorine in its manufacture. It is probable that other vesicants may appear on the battlefield in the future, but they will possess characteristics similar to the type agent, mustard gas.

A powerful vesicant with little odor, increased volatility, and of low or moderate persistency, would be important and has been sought for years. In fact the present war has introduced a new class of vesicants which might be used, classified under the general term of nitrogen mustard gases. These chemicals have been described in international technical journals and most of them are well known from a technical standpoint. The Germans are reported to have made them and to have stocks on hand for possible use.

The nitrogen mustards (HN) range from liquids to low melting point solids and vary in color from a colorless compound to a pale yellow, depending upon the specific compound as well as the degree of purification. They are practically odorless or, at the most, possess a slight fishy odor which is characteristic of the amines and derivatives. This fact is of great importance.

The nitrogen mustards are less vesicant in action than mustard but have a peculiar and characteristic physiological effect on the eyes which goes beyond mere irritation. They have low freezing points.

The more volatile members of the group permit obtaining higher vapor concentrations in the air even though they are not as vesicant as mustard. These agents have a much less marked odor than other war gases; and concentrations which are toxic are not readily detected by smell, particularly when shells containing the agent are employed along with high explosive.

The nitrogen mustards are more dangerous to the eyes but less vesicant to the skin. For example, blindness results in from 1 to 6 hours, while blistering action may be delayed 24 hours. Death due to inhalation may be delayed up to four days.

◇ VI ◇

THE TEAR GASES AND OTHER AGENTS

TEAR gas was one of the first chemical agents to be used in modern war. Indeed, the Germans claim that the French initiated gas warfare by their use of tear gas in hand grenades in August 1914, several months before the first cloud gas attack took place. Both French and Germans used tear-gas shells beginning about April, 1915; the British followed somewhat later, and all used them to some extent throughout the war for harassing. Tear gases, or lacrimators, are substances which irritate the eyes causing involuntary weeping. Although the tear gases do not cause serious or permanent injury, they are valuable in war because infinitesimal amounts in the air will make a man put on his gas mask.

Wearing a mask entails a definite loss in efficiency. Where the object is to harass, to cause delay, or to cause confusion, it may be cheaper to use a tear gas than to use a more toxic gas which must be employed in much larger quantities. Where the tactical need is to hamper the enemy's operations, one shell filled with a powerful tear gas may do the work of ten mustard-gas shells. It has been proposed to combine small amounts of a solid tear gas in all high-explosive shells. This is possible without reducing materially the high-explosive effect of the shell. Russian chemical war-

fare texts suggest the use of a so-called "splinter chemical shell," which on detonation produces casualties from its explosive effect and at the same time sets up a tear-gas concentration in the air.

One of the tear gases used during World War I, known as BBC, produces an intolerable effect on the eyes after three minutes' exposure to a concentration of eight ten-thousandths of an ounce (.0008 ounces) per thousand cubic feet of air. This is an extremely small concentration and one that can be obtained over a large area with an expenditure of a few artillery shells.

Tear gases have found their principal use since the war in training and in civil disturbances, such as riots, or in the control of prisoners in penitentiaries. They have proved valuable in breaking up mobs and in quelling disturbances without injury to the participants. There is some doubt whether they would be used in wartime in view of the fact that the gas mask gives complete protection, and even without the mask tear-gas casualties rarely need to be hospitalized. Nevertheless, there is always the possibility that they may be used in small amounts just to cause masking, and to harass.

A persistent tear gas placed on the ground makes any area an uncomfortable place to be without a gas mask. For the purpose of harassing, preventing troops from sleeping or resting, and for causing delay and confusion at small expense in effort or munition tear gas appears to have sufficient value to make it useful in any war in which chemicals find widespread use. It will always be valuable as a training agent.

J. B. S. Haldane says:

Lacrimatory gas was only once used under ideal conditions—by the Germans in the Argonne in 1915. They captured a fairly

extensive French trench system and about 2,400 prisoners, almost all unwounded, but temporarily blind. When they gave the number of prisoners, the French authorities not unnaturally protested that this number was practically equal to the total of their casualties. And this was quite true. The French were unprotected. They were deluged with shells giving off a vapour which temporarily blinded them. They could not even run away. The Germans walked across, removed their rifles, and formed them up in columns which marched back, each led by a German in goggles.

There are a great many tear-gas compounds, but they differ in effect chiefly in their intensity. It is necessary to mention in detail only the standard lacrimators, CN and CNS (CN solution). CN, chloracetophenone, is the tear gas which has been developed by the Chemical Warfare Service of our Army since the First World War. It was not used during the war. CN is a white or gray crystalline solid having a pleasant aromatic odor which somewhat resembles locust blossoms. Being a solid it gives off very little vapor and yet the presence of particles of the solid in a closed room would very quickly become apparent to the eyes since such a small amount of CN in the air is irritating. It is highly persistent, but in cold weather this fact would not be important because low temperatures will prevent any evaporation and, hence, any tear-gas effect. CN is very stable and can be heated to high temperatures without decomposition. Its high stability makes it possible to mix CN and detonate it with TNT in high-explosive shells without losing any tear-gas effect. Stability to heat makes it possible to mix it with smokeless powder in burning type munitions where it is dispersed by the heat of the burning powder as a cloud of small solid

particles. It is by means of detonation or burning that it is used in the solid form.

The fact that CN dissolves in benzene, carbon tetrachloride, chloroform, and chlorpicrin makes possible the other standard tear gas, CNS, or CN solution. CNS is a mixture containing CN, PS (Chlorpicrin), and chloroform. This is the standard liquid tear gas. CNS is much less persistent than CN. In the summer it has a persistency of about one hour in the open and two hours in wooded areas. In cold weather this persistency would be increased from six hours in the open to a week or more in the woods. I do not entirely trust these figures for persistency, for I have experienced much annoyance from tear gas more than a day after the gas was supposed to have disappeared from a wooded area. Generally, however, they may be depended on.

CNS has the same effect as CN and its properties are those of CN in a solvent. The odor of CNS combines the odor of PS and CN. It has been compared to the odor of fly paper. I disclaim any responsibility for the comparison. It is the official description given in the U. S. Army Chemical Warfare Field Manual. High concentrations of CNS cause violent irritation of the eyes, vomiting, and to many individuals, an irritation of the skin. Twelve-thousandths of an ounce (.012 ounces) of CN in a thousand cubic feet of air is considered a harassing concentration.

Another solution of CN is called CNB. This is a mixture of CN in benzene. It was used in peace time training and is somewhat less irritating and easier to handle than CNS.

CN combined with smokeless powder is used in tear-gas candles and grenades, and CN is suitable for use in artillery

and chemical mortar shells. CNS is suitable for use in artillery and mortar shells and may be sprayed from tanks on airplanes to produce sudden and extremely high concentrations on the ground.

BBC (brombenzylcyanide) is the only tear gas that was manufactured by the Chemical Warfare Service in any quantity during World War I and only about five tons of it were made here. It was used in large amounts by the French, loaded in artillery shells. The French called it camite and gave it the code symbol CA. BBC is a heavy, oily, dark-brown liquid which has an odor like sour fruit. It is very persistent, lasting several days in the summer and several weeks in the winter. Although it is a more intense tear gas than CN and its action is more effective in low concentrations, it is not as satisfactory for military use since it has much less stability than CN. It attacks common metals with the exception of lead. In steel shell it rapidly corrodes the metal and in the process decomposes itself, losing its tear-gas properties. Artillery shells, therefore, must be lined with lead, glass, or porcelain if they are to contain BBC. The British have used BBC as a standard tear gas.

During World War I several other materials were used as tear gases. The principal lacrimator used by the British was SK (ethyliodoacetate). The Germans used T-Stoff (xylyl and benzyl bromide), a powerful lacrimator effective in concentrations of one volume in one million volumes of air, and K-Stoff (a brominated methyl-ethyl ketone also called B-Stoff) which was intense and quick-acting and somewhat less persistent than T-Stoff.

The French used a large number of materials with names such as tonite, cyclite, martonite, and bretonite. These com-

pounds were all somewhat similar in their chemical nature and varied chiefly in the intensity of their effects.

Vomiting Gases or Irritant Smokes

When the chemists started their search for toxic chemicals for use in war, one of the earliest possibilities thought of was arsenic. Arsenic compounds are widely known for their poisonous nature of which commercial use is made. The only simple arsenic compound that showed any promise was arsine —highly poisonous and a gas. It proved to be too unstable and inflammable, however, to be of any use.

Investigation of the more complex arsenic compounds brought to light a number of possibilities and many of them were found to be useful in chemical warfare. The best known examples are: L (Lewisite), MD, ED (dick), DA, and DM. The Chemical Warfare Service up to the present time has adopted only three of these arsenic compounds as chemical agents: L, DA, and DM. L and ED have already been discussed as vesicants.

DA (Blue Cross) and DM (Adamsite) resemble each other closely. These two compounds are placed in a separate class among chemical agents—the vomiting gases or irritant smokes. They produce their effect by being liberated in the air as a smoke, as finely divided solid particles, and not as a vapor like phosgene, or as a mist like mustard.

The fact that these particles are solids, makes a lot of difference in our gas masks. The solid particles cannot be absorbed by the chemicals in the gas-mask canister as are gases and, therefore, must be filtered out mechanically. The finer the particle, the harder to filter it out and also the greater the irritant effect.

Very minute irritant smoke particles produce severe toxic effects, while larger ones merely produce excessive sneezing. When these chemicals were first used they were called sternutators or sneezing compounds.

Some compounds are known whose effects are entirely limited to intense sneezing; but DA and DM, when properly dispersed, have marked toxic properties. They are violent irritants to the nose and throat, and also cause vomiting and great distress. An unprotected man may be sick for a day or so, but these smokes seldom if ever kill in concentrations possible in the field.

The Germans introduced DA as a chemical warfare agent; it was first used July 10, 1917. The early German practice was to place a bottle of DA in a shell and surround it with explosive. DA was the active agent of the German Blue Cross shell.

The Germans had a clever scheme for using Blue Cross (DA). The early gas masks provided no protection against the Blue Cross smoke. The scheme was to start an attack with Blue Cross shells. This caused sneezing and nausea. It is not possible to wear a gas mask and sneeze or be violently nauseated. The masks had to come off. Then the enemy sent over phosgene or some other deadly gas to polish off the job. That was the idea. Fortunately, however, it did not work long, since the Allies were able to place effective filters in their masks soon after the first Blue Cross attacks.

DM or Adamsite is the standard irritant smoke of our Army. Its chemical name is enough to terrify any but a hardened chemist—diphenylaminechlorarsine. The reader may safely forget this name, however, for it is always referred to as DM or Adamsite. Dr. Roger Adams was the

discoverer. In the pure form it is a bright canary yellow crystalline solid. The commercial product is generally dark green but is sometimes dark brown, depending on the impurities. It is practically odorless, but when dispersed as a smoke by the heat of burning smokeless powder it forms a bright yellow cloud with a characteristic smoky odor. The odor, however, usually is not noticed because of the burning sensation in the nose and throat which is the first symptom produced.

DM can be heated to fairly high temperatures without being destroyed. It may be placed in a shell surrounded by high explosive and detonated without appreciable decomposition. In this way it may be dispersed in the air as finely divided solid particles. It is affected very slowly by water. Strong alkalies, such as soda lye, will destroy DM. Chlorine vapor will affect its toxic properties. DM has a marked effect on iron, steel, and brass; however, the action seems to be limited to the surface where the DM and the material are in contact, and action does not extend below the surface. Since DM is a smoke borne by the wind, its persistency depends upon the movement of the air; it generally lasts about ten minutes.

Because it is impracticable to obtain a killing concentration except in an inclosed space and since the effects of Adamsite disappear in twenty-four to forty-eight hours, it must be considered as a harassing agent. During the period a man is affected, however, he is a total loss to his commander. A concentration of two-thousandths of an ounce (.002 ounces) in a thousand cubic feet of air is sufficient to harass. DM was never actually used during World War I. When more suitable methods are found for dispersing it on the battlefield, it may be used. It is immediate in its action and is

effective in lower concentrations than most other gases. When properly dispersed only the best gas-mask filters will remove it from the air. The slightest injury to the filter permits the passage of the irritant particles and consequent removal from action of the wearer of the mask. It has been used effectively for many years by peace officers in the control of civil disturbances.

Nerve and Blood Poisons

The final class of toxic agents includes those which attack the nervous system and bloodstream. None of them have yet been successfully used in war and yet this class provides an ever-present threat.

Hydrogen cyanide (AC) is representative of the nerve poisons. It acts principally on the nerve centers and causes death by paralysis of the central nervous system. AC has always been recognized as one of the most powerful of all poisons. It is used today in some states for the execution of criminals. During World War I the French were the only combatants to use this agent. They called it Vincennite and loaded it into 75-mm. artillery shells. In these shells the hydrogen cyanide was mixed with other materials to increase the stability of the substance and to make it heavier so that it would remain close to the ground. Vincennite shells proved very ineffective. Although the French used hundreds of thousands of them and continued the use until the end of the war, there is no evidence that any material number of casualties were produced. There is a good reason for the failure of Vincennite as it was used by the French, and this failure should not lead to the belief that AC may not yet be used with success.

The poisonous effect of AC is not cumulative. Therefore, small or moderate concentrations fired over a long period of time, will not produce a similar effect to that of a large concentration fired in a short time. The body is apparently able to throw off the effects of small amounts up to a certain "threshold" concentration. Below this "threshold" concentration there is no effect. Above this concentration, if the AC is absorbed for a short time, poisoning is rapid and death follows quickly. When contained in a small projectile, such as a 75-mm. shell, which can hold only little more than a pound, it is impossible to place on the target enough shell to create the "threshold" concentration except in the small area in which the shell bursts and then only for a moment. No commander would have available sufficient cannon to permit the delivery of the sudden high concentration necessary before the man on the target could get his mask on. Used in a larger caliber weapon which, employing high-capacity projectiles, would deliver heavy concentrations suddenly on a target, there is every reason to believe that this extremely toxic agent would prove most effective. During the First World War, hydrogen cyanide was never used in this way. It thus received a black mark which may be entirely unjustified and which certainly should not lead us to minimize the possibilities of hydrogen cyanide.

AC is relatively unstable to shock. It is also unstable on long storage, although the addition of small amounts of certain other chemicals will prevent decomposition. AC is a colorless liquid that becomes a gas at 79° F. It has an odor like bitter almonds or crushed peach kernels. It is just a trifle lighter than air, a decided disadvantage. If used in a large capacity munition, this disadvantage may be reduced. It is, of course, extremely non-persistent. AC is difficult to

protect against. An excellent gas mask and skill in its speedy adjustment is required. High concentrations can easily penetrate a poor gas mask. AC is a gas that we must be prepared to reckon with.

Cyanogen chloride (CC) was used by the French during the First World War, alone and mixed with arsenic trichloride, the latter called Vitrite. CC, while very toxic, breaks down easily. In addition to being a systemic poison only slightly less effective than AC, it is a powerful tear gas. It differs from the latter in that its effect on the body is cumulative and therefore it is more useful in low concentrations for long exposures. It offers great possibilities as a war gas.

The other agent within the class of blood poisons is carbon monoxide. This gas is formed by every bursting shell, by every blast of a cannon, and in every fire which burns in a closed space. It is the same gas which comes out of automobile exhausts. Probably it has caused more deaths than all the other gases put together. The Army gas mask gives practically no protection against carbon monoxide. CO is colorless, odorless, and tasteless. It would be a chemical agent par excellence to provide surprise, if two difficulties could be overcome. The first one is that it is light and diffuses very rapidly. In a closed space a carbon-monoxide gas shell would be effective but unnecessary since the bursting of the ordinary high explosive shell in a closed space would do the work equally well. The other difficulty is that carbon monoxide is relatively incompressible. It cannot be held as a liquid in the ordinary shell or cylinder. There would be no way of getting sufficient amounts of it on the battlefield.

There are a number of other substances which act in a manner somewhat similar to AC or carbon monoxide, but none of them have properties which would indicate great promise as chemical agents.

◇ VII ◇

THE SCREENING SMOKES AND THE INCENDIARIES

ONE of the most important developments of the First World War was the use of screening smoke. Although there have been attempts throughout the history of warfare to make use of smoke to conceal movements during battle, there was no widespread or planned application of smoke tactics by land forces until the summer of 1915. By the time of the Armistice the use of smoke by all of the armies had become well established. Today smoke is widely used by all combatants to screen operations to conceal vital spots within critical areas and for purposes of deception.

From a chemical warfare point of view, a screening smoke is a cloud of extremely small solid or liquid particles suspended in the air. A smoke screen accomplishes its purpose by scattering rays of light through reflection caused by the many individual particles suspended in the air, and also to some extent by actual obstruction of the light rays. The scattering of light rays by smoke particles is dependent on the number and size of the particles in a given air space. The more of them there are the more complete will be the scattering or diffusion of the light. Consequently, a smoke generator should produce a screen made up of very fine particles because in this form the material will remain suspended longer and also because a given quantity of smoke material will yield

a large number of particles and, hence, will be more efficient. It should be noted, however, that size can be too small to be effective. Color also is a factor.

A dust cloud behaves much the same as a smoke screen. In fact, in both cases the air holds suspended myriads of extremely small solid particles. Smoke particles are smaller than most dust particles and so form a better screen, but where you have a very fine dust and quiet air, the same effect is produced as with the smoke. The dust scatters the rays of light and obstructs them so that you can't see beyond the dust. Doubtless many instances could be found in history in which dust clouds have saved the day for a military force by concealing its movement. In the days of the American Revolution when Kentucky earned its name and was truly the "dark and bloody ground," a dust cloud played its part in the relief of the settlers at Bryan's Station near Lexington. Besieged by 300 Wyandots and a number of white soldiers under British leaders Caldwell and McKee, with Simon Girty (the white Indian) and his brother, the little garrison at Bryan's Station had finally gotten word of their plight to Lexington. Major Levi Todd and thirty riflemen, together with Captain William Ellis and sixteen or seventeen horsemen, went to the relief. John Bakeless, in his *Daniel Boone*, tells the story of how Captain Ellis and his horsemen got past the Indian band, which was waiting to ambush them, and into the fort:

Ellis now led his handful of cavalry straight into and straight through the Indians' trap. They rode, if not into the jaws of death, at least into the best imitation of hell that the very considerable ingenuity of the American Indian could provide. For a hundred yards they ran the gauntlet of the fire from the am-

bushed warriors, while the men at the fort, hearing the uproar and then seeing them emerge, got the gate open.

Incredibly, every man and every horse came through without a scratch. Indians were proverbially bad marksmen; a galloping horse is not a really good target; and with the single-shot firearms of the day most of the Indians got only one chance at them. But legend also says that they got through because of "the great dust that was raised by the horses' feet." The experience of the World War and after shows that smoke screens do reduce the accuracy of rifle fire almost to nothing. It was August and the buffalo trace was dry enough for sixteen or seventeen horses, ridden at a mad gallop, to produce a very fair screen.

There are three principal methods for producing smoke on the battlefield. One is by burning a smoke-producing substance, another is by the explosion of a shell containing smoke material, and the third is by spraying into the air a chemical which will combine with the water vapor in the air to form a dense cloud, or a mixture which will remain suspended as a fog.

For convenience, smokes may be divided into solid smokes and liquid smokes. Typical of the solid smoke is WP (white phosphorus). Phosphorus is chemically very active. It combines with the oxygen in the air readily. When this combination takes place rapidly, clouds of heavy white smoke are formed. WP is important as a smoke producer, but it also is important in chemical warfare because of its burning effect on personnel and material. This burning action makes it an effective casualty producer. In shell and bombs phosphorus is an extremely effective munition, useful for many purposes.

Phosphorus exists in two forms, white or yellow phosphorus (WP), and red phosphorus. Red phosphorus, the

kind on the side of the match box used for lighting safety matches, is much less active chemically, burns less easily than the white variety, and is not of great importance as a military smoke-producing agent. White phosphorus, which is very important in chemical warfare, is a pale yellow, wax-like solid. It is so active chemically that if exposed to the air at ordinary room temperatures it combines with the oxygen spontaneously, and the heat generated causes it to burst into flame. Therefore, WP must be kept under water during storage in order to protect it from the air. It is very poisonous; phosphorus burns on the skin are painful and slow to heal. A piece of WP the size of a matchhead splashing on the clothes may cause a severe burn.

WP melts at about 111° F. and, therefore, may be loaded directly into artillery and mortar shell and bombs by melting and pouring under hot water. The loaded WP munition contains a small bursting charge of high explosive so that when detonated the solid phosphorus is scattered into the air in small pieces. The heat generated by the bursting charge ignites these fragments immediately and a white cloud (phosphorus pentoxide) is formed. Some of the small particles of this oxide of phosphorus combine with the water vapor always present in the air to form an acid of phosphorus. The mixture of small particles of oxide and acid produces a most effective white screen. Although phosphorus is poisonous, the smoke itself is harmless.

Phosphorus munitions combine smoke and casualty effect and in addition have incendiary value since the burning phosphorus will set fire to dry combustible materials. Smoke clouds produced by burning phosphorus have a disadvantage in that the heat of burning causes the smoke to rise high above the ground and thus some obscuring value is lost.

Another solid smoke is HC mixture, which is the standard burning type smoke material used for training purposes in the U. S. Army. HC is a combination of zinc powder and hexachlorethane, with the addition of small amounts of two or three other chemicals to control reaction. Hexachlorethane mixture is used in smoke candles, pots, grenades, and shell. The zinc and the hexachlorethane combine under the influence of heat generated by a fast-burning starter mixture to produce zinc chloride and free carbon which pass off as a heavy grayish white smoke. During the First World War materials similar to HC were used to form smoke clouds statically, at points where it was desired to conceal movements or operations.

The type agent of the liquid smokes is FS. FS is a solution of two acid materials, sulfuric anhydride, which is the same as sulfuric acid from which the water has been removed, and chlorsulfonic acid, which is made by the action of gaseous hydrochloric acid on sulfuric acid. FS is almost twice as heavy as water. It freezes at — 22° F.

It is an excellent smoke producer, the smoke resulting from a combination of the particles of FS with the moisture in the air to form sulfuric acid and hydrochloric acid. It can, therefore, be understood that FS is highly corrosive to metals and fabrics. Although the smoke is harmless, it irritates the skin and throat. It is used chiefly from airplane spray tanks. As the liquid flows from the tanks the drops are broken up by the air stream into a spray which, combining with the water vapor in the air, forms a dense cloud which settles gradually to the ground. FS also has an important use in artillery and chemical mortar shells. In these munitions a

small bursting charge throws the liquid into the air as a spray when the shell is exploded.

The Germans have made wide use of chlorsulfonic acid smoke in several types of smoke-producers. During the First World War they used large metal pots in which that acid in an upper container was allowed to drip on lumps of quicklime at the bottom of the generator. A dense white smoke resulted from the reaction. These pots were made in three sizes, the largest the Nebel-Trommel weighing about 200 pounds, the Nebel-Topf weighing 150 pounds, and the small Nebel-Kasten 75 pounds.

Similar smoke-producers are in use during the present war and a modification of the pots or a generator in which FS is sprayed or is injected into the hot exhaust manifold of an engine probably produced the large white smoke screens used at Brest in occupied France to blanket the Scharnhorst and Gneisenau when they were subjected to almost daily bombings by the R.A.F.

On account of its corrosive nature care has to be taken in peacetime, when spraying FS from airplanes, to protect government and private property. A few years ago during an army demonstration several airplanes sprayed FS over the city of Los Angeles from an altitude of more than 5,000 feet. It was thought that at this height the droplets would all be dissipated to a fine mist and blown away before reaching the ground. Unfortunately the air was particularly dry and weather conditions were such that the FS reached the ground in droplets big enough to illustrate forcibly the corrosive effect of an acid smoke on automobile finishes, clothing, and various other materials. The damage claims reached a tremendous figure. Drops of FS play havoc with paint, cloth, and shiny metal surfaces. In handling FS, it is treated in the

same manner as any strong acid. For example, rubber gloves should be used.

FS is low in cost, easily available, and not difficult to manufacture. Before the use of FS, the standard liquid smoke was FM (titanium tetrachloride). FM is a heavy colorless liquid which combines with the moisture in the air to produce a heavy white smoke which is harmless and only slightly irritating. FM is expensive, costing about four times as much as FS, and has an added disadvantage that traces of moisture cause the formation of a solid, gummy material which clogs spraying apparatus. FM is no longer used by the U. S. Army.

Crude oil has found wide use as a smoke producer especially by naval craft, and in stationary smoke pots employed for large-area smoke screens. In both cases the smoke is formed by incomplete burning and evaporation of the oil. Destroyers and other naval vessels use crude-oil smoke to produce large smoke screens at sea to cover their maneuvers.

Airplane factories, munitions works, power stations, bridges, and similar installations are important and legitimate targets for long-range bombardment airplanes. Anti-aircraft defense has progressed to such an extent that attacks on these objectives are generally made at night to avoid excessive losses. Trained bombardiers can hit such targets on moonlight nights even when they are blacked out and with the aid of flares can locate them when there is no moon.

Smoke has been used by all the combatants to prevent aerial observers from picking out these targets. Unless lights are showing on the ground the smoke need not obscure completely. It is effective if it distorts or absorbs enough of the reflected light rays from the moon or the flares to make recognition of the ground features difficult.

One widely used method of producing the extensive smoke screens required to protect vital points is the partial burning and distillation of oil. This is accomplished in the oil-smoke generator, a development of the orchard heaters used in California. A metal pot serves as basin for the oil and combustion chamber. Attached are a sheet metal chimney and devices to regulate the draft. When burned in the generator, low-grade fuel oil or crankcase drainings give off a dark gray smoke which blankets surface objects from air observation at night. The smoke has little value for blanketing vital points during the day. At night however it has proved very effective. Observed from the air this screen has all the appearance of a pond or lake or ground haze.

A more recent development in large-area screening increasingly used is a mechanical method for producing a very persistent fog which remains suspended in the air for a long time and which travels with the wind for great distances. The generator can be mounted on a vehicle and moved to take advantage of the wind. It produces a white smoke or mist of maximum screening value, effective in daylight as well as night. The new oil fog generator, which is designated Smoke Generator Mechanical M1, has proved its value in active operations in North Africa, Sicily and Italy. I know of no vital point which has been successfully bombed while the large-area smoke screen was maintained.

When smoke is released into the air either as a result of an explosion, burning, or spraying, the cloud is blown by shifting air currents. These air currents cause a spread of the cloud laterally. In addition, the cloud is carried along the ground with a rolling motion which causes the cloud to stretch out in length. Increase in length of the cloud is called the drag effect. Finally, there is a vertical rise which is due

to heating and to convection currents of air, which are especially active over dry ground when the sun is shining brightly and, hence, when the ground is warmer than the air. All of these factors play their part in the travel of a smoke cloud.

INCENDIARIES

Chemical warfare has always included fire as well as gas and smoke. In the early days of the last war chemical warfare units were called gas and flame companies. In 1943 as in 1940 flame was the most prominent of the team of gas, flame, and smoke. Certainly in Europe fire has been running explosives a very close race for the doubtful honor of causing the greatest damage.

All incendiary devices require the use of materials which are spontaneously inflammable or which can be set on fire easily by a spark or by the flash of an explosive. Frequently the incendiary device contains a combination of two or more combustible substances, a part of which can be ignited easily, and the remainder of such character that they will produce an intense flame over a long enough period to assure setting fire to the material which is to be destroyed. In some cases an intense flame is obtained by the action between a material that burns easily and an oxidizing agent. In this case an example of an oxidizing agent would be a substance such as saltpeter or chlorate of potassium, a substance having large amounts of active and available oxygen. Oxygen is always required for burning, and generally where you have an agent containing available oxygen and material which will burn easily, moderate increases in temperature will start fire. In some incendiary munitions there is included a light charge

of explosive for the purpose of scattering the burning substances.

There are a tremendous number of combustible materials and mixtures which have been used as incendiaries. Fire has been used as a weapon of war since the dawn of history. In the wars described in the Bible there are many instances of the use of burning oil and of fire compositions against fortified cities. Throughout the Middle Ages incendiary devices of one kind or another were used, and in the present war the incendiary has been constantly in use.

While there are a great many kinds and combinations of combustible materials, most of them can be grouped into one of the following classes: spontaneously combustible solids—white phosphorus; mixtures of finely divided aluminum or magnesium with oxygen-containing compounds—thermites; mixtures of oxidizing agents (nitrates, peroxides, chlorates) with carbon, sulfur, aluminum, and other substances which burn easily; inflammable materials, such as oil, gasoline, and tar products; solid oils; spontaneously inflammable liquids.

White phosphorus is one of the first materials that recommends itself for use as an incendiary, to a person familiar with its properties. The fact that it starts burning of its own accord at ordinary temperatures and that it gives out a great amount of heat makes it natural to think that it would be an excellent incendiary. It does have a value as an incendiary but, as a matter of fact, it is inferior to most other materials used in war for setting fires. It will ignite such things as dry grass and leaves, inflammable liquids, such as gasoline, and, under favorable conditions, dry wood. However, things that are not easily ignited, as, for example, large pieces of hard wood, are not readily set on fire by white phosphorus.

This is due largely to the fact that although a great deal of heat is given out when phosphorus burns, this burning can take place only on the surface of the phosphorus since it requires air. Therefore, the heat is evolved only gradually. Furthermore, the heat is rapidly dissipated in the inert gases of the air and, consequently, the temperature does not rise very high. When phosphorus burns it forms a protective coating of phosphoric acid on the material with which it is in contact and this coating helps to stop the burning. Phosphorus, therefore, is not used solely for its incendiary effect but rather because of its effectiveness as a smoke-producing material. It does have an extremely important incendiary effect on men and animals and, therefore, phosphorus should be considered not only as a smoke and incendiary material but as a casualty-producing agent. Phosphorus is used as a part of certain other incendiaries and in incendiary and tracer bullets.

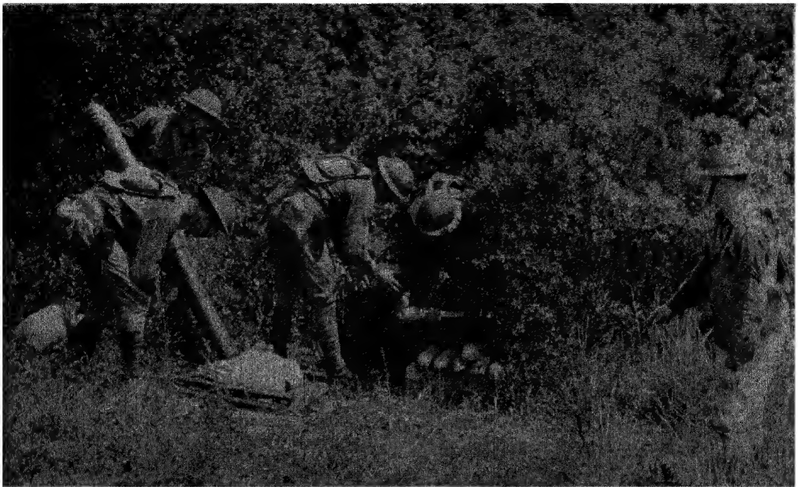
Thermites are valuable incendiaries because they not only generate a large amount of heat but this heat is liberated very quickly and is concentrated. Thermite is typical of the second class—that is, mixtures of finely divided aluminum or magnesium with oxygen-containing compounds. The action between the components of the mixture does not require air since the oxygen needed for rapid burning is contained in the mixture in a concentrated form. Consequently, with no inert gases present to conduct away part of the heat and with the necessary oxygen concentrated in small volume, a very high temperature is reached when thermite burns. Temperatures of about 5,400° F. are obtained when the ordinary thermite reacts. This reaction is a combination between magnetic oxide of iron and aluminum. An igniter, which is

a faster-burning mixture, starts the thermite burning. The product is aluminum oxide and molten iron.

Chemistry instructors used to illustrate the tremendous heat generated by thermite with a lecture table experiment which was calculated to open the eyes of a freshman. Perhaps they still use this demonstration. A layer of sand was placed in a battery jar. A tripod on top of which was a pie plate was next set up inside the jar, and water was added until at least an inch of it covered the plate. About six or eight inches above the jar was fixed a small paper cartridge containing thermite. After explaining the nature of the compound the professor with a flourish would light the thermite using a piece of magnesium ribbon as a fuse. The mixture flashed for a moment, then a cloud of steam rose as the molten iron formed by the reaction hit the water, burned its way through the tin pie plate and dropped sizzling to the bottom of the jar where it finally was quenched. A show like that made the student remember that thermite burned with enough heat to produce molten iron and could be used for welding steel rails. It is one of the most powerful incendiaries we have, capable of burning through the top of a steel oil tank.

The Japanese were given an even more convincing and spectacular demonstration of the effectiveness of thermite, according to their own reports, when Brigadier General James Doolittle, M. H., and his air raiders bombed military objectives in Tokio, April, 1942. The day after the raid Japanese broadcasters announced that small thermite bombs were the incendiaries dropped on the city by the American flyers.

This was the first large-scale use of incendiaries by American forces in the Second World War and the first time in history that our air force had employed incendiary bombs in



CHEMICAL MORTAR IN ACTION

This is the principal weapon of chemical combat troops.

A BATTERY OF LIVENS PROJECTORS

(Semi-surface set up shown—full surface set up now possible permits more rapid installation.) Exploder box in grass at extreme right.

an important attack. I talked with General Doolittle soon after his return from the raid and he remarked especially upon the highly successful incendiary action of the little bombs. He said he could see the patterns of the small bursts of flame behind him as he flew over Tokio after releasing the bombs and that a second wave of bombers about fifteen minutes later reported the entire section was burning vigorously.

In ordinary thermite, red oxide of iron is substituted sometimes for the magnetic oxide. A number of other thermites may be made by substitution of other oxides for those of iron and by substituting magnesium for aluminum. In the present war mixtures of this nature or other mixtures of oxidizing agents are contained in a magnesium bomb body which itself burns. During the First World War thermite was frequently loaded into bombs, shells, and grenades, and was used by practically all the armies engaged.

Under the third class, there are great varieties of mixtures possible. Some of these mixtures are not very different from the thermites. They all contain some agent for supplying oxygen, such as nitrate of potash, saltpeter, chlorate of potash, or a peroxide, together with one or more of such materials as powdered charcoal, sulfur, magnesium, aluminum, and one of the many easy combustible compounds of carbon, such as turpentine, rosin, or asphalt.

The use of inflammable materials, such as gasoline, kerosene, and tar products, needs no discussion. These inflammable liquids are sometimes absorbed in such materials as cotton waste. This class of incendiary is used in the flame-

thrower, which will be discussed in a later chapter, and in oil bombs.

The class known as solid oils are mixtures of a liquid oil and some solid resin, soap, or other substance, in such proportions as to yield a more or less solid product or jelly. Gasoline with rubber or some jelling material is effective. Small pieces of metallic sodium are sometimes added to a solid oil to prevent easy quenching of the fire with water. Sodium will burn vigorously when brought in contact with water, and the oil fire would thus be rekindled by the material intended to put it out. Solid oil was used in certain of our incendiary bombs during the last war, and it is proving an effective fire producer in this war. Although the incendiary oils do not produce as intense heat as the thermites, they yield a greater quantity of heat over a longer time and may prove better fire producers.

Spontaneously inflammable materials, with the exception of phosphorus, have not yet proven of practical value although many have been tested. They are difficult to control and constitute a great hazard on storage. However, there are a number of substances which ignite spontaneously on contact with the air, and methods may be discovered for making practical use of one of them.

The combatants in the present war have all used spontaneously inflammable phosphorus devices for firing dry wooded areas and ripened crops. Food is one of the sinews of war. Blockade and starvation are today, as they always have been, vital factors in the grand strategy of all warring nations. The destruction of the enemy's food crops therefore is a legitimate and important objective of the armed forces.

One type of incendiary for burning grain fields called the "incendiary leaflet" is made by pressing a piece of phos-

phorus between perforated sheets of thin combustible material. When dry the air reaches the phosphorus through the holes in the material and the leaflet takes fire spontaneously. Another type, used by the Germans, is a disc of crepe rubber nine inches in diameter and three-fourths of an inch thick, containing a phosphorus compound which bursts into flame when dry. Until ready for use these devices are kept under water as they are dangerous to handle when dry.

The leaflets are sowed by the thousands from airplanes and scattered broadcast over ripened standing or harvested crops, or on wooded areas in dry seasons to burn woods and forests. Under some weather conditions it may take several hours for them to dry out but in dry weather they burst into flame in a few minutes after reaching the ground and set fire to whatever light material they happen to fall on.

Finally we should not overlook the good old-fashioned bonfire which is also playing its part in the present war. Fake fires are used to decoy bombers away from real targets and cause them to bomb isolated spots where no harm can be done. For night bombing it has been a practice for the first wave of bombers to find a target and drop incendiaries. The fires resulting lead the next wave to the place to be destroyed and make a perfect target. Large bonfires set intentionally on the outskirts of a city at the time of the first assault have succeeded in drawing off the attack and resulted in much useless expenditure of ammunition. Thus fire plays a defensive part as well as an offensive part. Just as it is the servant of man in the home, if properly controlled, so the agent of destruction becomes the savior of a city when skillfully used.

Part Two

Chemical Weapons and Their Use in Battle

◇ VIII ◇

THE GROUND WEAPONS OF CHEMICAL WARFARE

FOR each situation in which a chemical weapon can be used, someone must answer the question: "What is the proper weapon?" The answer to this question depends upon how much chemical agent must be placed on the target; the distance to the target; how quickly the chemical must be put down; how much time is available before it must be put down.

If a special weapon is designed for the purpose of dispersing a chemical agent, there must be a requirement for it not met by any existing weapon. Not many of the weapons used for firing explosives are suitable for projecting chemicals. An efficient chemical weapon must have mobility, ease of handling and movement, rapidity of fire, high capacity for chemical contents, and sufficient range (the mass of chemical fire is generally at short or intermediate ranges). Cheapness and ease of procurement and high angle of fire are desirable.

Certain chemicals, notably the non-persistent agents, such as phosgene, must be placed on the target in maximum quantities, in a minimum of time. This means high shell capacity, rapid rate of fire. The long-range weapons designed for high explosives are necessarily deficient in this respect. For example, the 75-mm. gun was not designed to fire a high-ca-

pacity shell at a rapid rate. The 75-mm. shell is thick-walled and holds little chemical. It is entirely unsuitable for firing a non-persistent agent. It is, on the other hand, one of the best weapons for firing mustard gas, which, because of its high persistency, can be placed on the target over a long period of time.

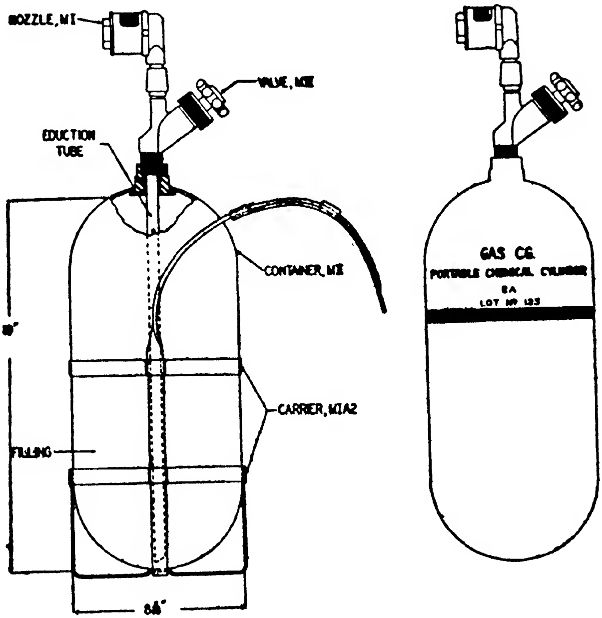
In order to meet the need for a weapon which will place on a target a large amount of chemical in a short time, three special weapons have been developed for use by chemical troops and are now standard for dispersing chemical agents. They are the portable cylinder, the Livens projector, and the 4.2-inch chemical mortar.

The Portable Gas Cylinder

The portable cylinder is a gas container intended to be brought up in large numbers from rear areas by chemical troops and discharged at points on the front close to the enemy. The attack using the cylinder is called the cloud attack and was the first method of projecting gas. Although dependence on wind direction and weather conditions limit its use, and the development of other weapons has relegated it to a secondary status, the gas cylinder may yet have some use as a weapon of opportunity.

This weapon is a thin steel cylinder about nineteen inches high and eight and one quarter inches in diameter, loaded with thirty to thirty-two pounds of non-persistent agent, and provided with a valve for its release. When the valve is open, either by hand or by an electrical firing attachment, the compressed liquefied-gas filling is forced out under its own pressure, immediately vaporizing and forming a gas cloud. Each cylinder weighs about 50 pounds when filled,

and is a one-man load. It is carried on the back by means of two metal hooks which fit over a man's shoulders. Cylinders are suitable for use in large numbers under conditions of trench warfare or when the situation has stabilized temporarily and when there is a favorable wind blowing toward the hostile position. They can be brought up at night and fired quickly. No emplacement is necessary. They may even be fired from trucks or flat cars, as no recoil or explosion is involved in the release of the gas.



PORTABLE CHEMICAL CYLINDER
(with Nozzle and Firing Device)

A gas must have certain definite properties to be of value in cylinder cloud attacks. It must be extremely poisonous and

quick in action in fairly low concentrations. It must be a true gas at ordinary temperatures, like chlorine, or be capable of being mixed with some volatile gas. It must be heavier than air so that it will stay close to the ground. It must be obtainable in large quantities.

Phosgene is much more toxic than chlorine, but since it does not become a gas until 47° F. it does not develop great enough pressure, when used alone, to force the liquid phosgene out of the cylinder. Therefore, chlorine, carbon dioxide, or some other auxiliary must be used with it to generate the necessary internal pressure.

The value of a gas cloud lies in the fact that it is a high concentration of an active warfare chemical in vapor form advancing without the warning of shell bursts over the enemy's line. In a steady favorable wind of from three to twelve miles per hour a cloud can easily be launched covering several miles of front, and in such a high concentration as to penetrate all inferior and weakened masks. Such clouds have proved highly toxic after traveling six to eight miles from the starting point, and in a few of the biggest German attacks on the French front in 1915, civilian casualties were reported ten miles behind the front lines.

The Livens Projector

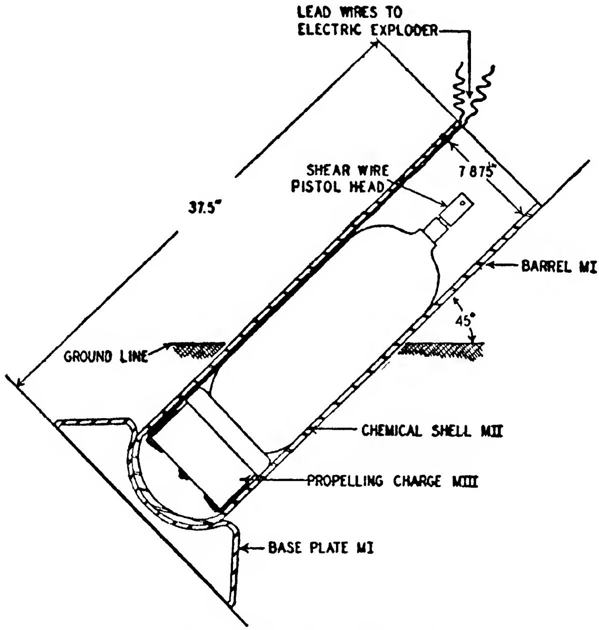
The Livens projector was developed by the British during the First World War for the purpose of placing a heavy concentration of gas on a target at fairly short ranges in a short time. The weapon was invented by a Captain Livens who saw the advantage of starting a gas cloud in the enemy's own lines. He, therefore, devised a large tube, closed at one end and big enough to hold a gas cylinder. It is said that he

made his first model by sawing off the top of a large-capacity gas cylinder. In the bottom he placed a charge of powder. On top of the powder he placed a smaller gas cylinder to which was fitted a simple fuse and burster designed to burst and blow off the head of the cylinder when the latter reached the enemy's lines. The charge was sufficient to project the cylinder the distance between the opposing trenches. From this crude beginning, the Livens projector, never a complicated weapon, was developed.

The Livens is a simple, smooth-bore mortar, consisting of a barrel, a base plate, a shell, and a propelling charge. The barrel is a steel tube two feet nine inches long and about eight inches in diameter, closed at one end. It rests against a steel base plate which is rectangular in shape with a depression to receive the barrel. The shells are light, thin-walled cylinders rounded at both ends and having an unusually large capacity. A tube which runs through the axis of the shell receives the burster, a smaller tube containing explosive and fitted with a 22-second time fuse. The propelling charge is a number of bags of smokeless powder of two different sizes in a tin can containing an electric squib in a small bag of black powder. Wires from the squib are long enough to extend past the end of the barrel when the powder is in place. Range is determined by the number of powder bags used. Maximum range of 1450 yards may be increased.

Projectors in batteries of 25 are emplaced about one foot apart in a shallow trench, each projector resting upon its base plate and pointed toward the target at an angle of 45 degrees. Propellant charges are inserted and wired in series for simultaneous explosion by electrical means. The projectiles are then slid down on top of the propellant and safety pins are pulled to arm the fuses. Only one round is fired by each projector.

A blasting machine or exploder is used to fire the battery. The electrical impulse, when the exploder is operated, ignites the electric squib which explodes the powder. This throws out the shells.



SEMI-SURFACE SET UP

LIVENS PROJECTOR

In spite of the fact that only one round can be fired from the Livens for each installation, the high chemical efficiency of the shell which contains nearly half of its total weight of sixty pounds in active chemical agent makes possible the delivery directly on the target of a higher concentration of agent with greater surprise than can be obtained with any ground weapon as yet available. Gas clouds similar to those

from cylinders can be started in the enemy's own lines. Although obsolescent, it remains a threat because the highest state of gas discipline and training is necessary to meet successfully a projector attack. Concentrations can be obtained that will put men out of action with a single breath. Perfect and instant adjustment of the gas mask is necessary. A projector is less dependent upon weather than the cylinder.

A projector attack was made by the Germans against one of the units of my own division in September, 1918. We had received warning of the attack, knew exactly where it was coming from and just what to expect. The unit was the best-trained and the best-led in the division. Troops were warned to be prepared and every precaution was taken to anticipate the danger. When the attack came approximately 200 projectors of phosgene were dropped in a small area within our trench system. The value of surprise, so necessary with a non-persistent gas, was entirely lost to the enemy, but in spite of this, out of some 300 men exposed, seventeen serious casualties resulted of which about one-half died.

The Mortar

Trench warfare in the First World War forced the development of much new material. Because the usual artillery weapons with their flat trajectory could not reach the men in the trenches, it became necessary to develop an all-round high-angle fire weapon. A flat trajectory weapon is one which fires its projectile along a fairly flat line of flight. With high-angle fire, the piece is pointed at an angle, generally above 45°, and the projectile goes high into the air in a curved line of flight.

After many devices had been tried with little success, a British officer found the answer in a high-angled mortar which

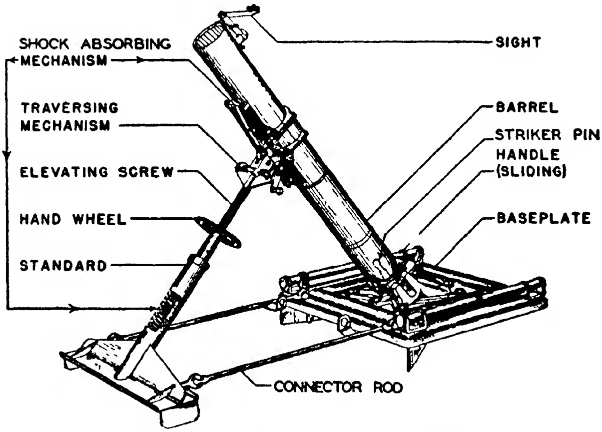
took his name and came to be known as the Stokes mortar. Like the Livens projector, it is simple in design and at first was not much more than a piece of iron piping closed at one end. Stokes' idea was to place the propellant charge and the primer, which detonated it, at the base of the projectile. The projectile then was allowed to slide by gravity to the bottom of the smooth pipe, where the primer struck a small projection, was ignited, in turn set off the propellant charge, and the explosion blew the projectile from the pipe in tumbling flight over into the enemy trenches where it burst.

The Stokes mortar was quickly adopted and immediately found wide and successful use. When in the summer of 1915 it became necessary to meet the needs of gas warfare for a device that was mobile, would fire rapidly, and deliver high concentrations of gas on enemy trenches, this weapon was adapted by the British to the new use. The original mortar had a three-inch bore. Its shell did not carry enough chemical to lay down an effective gas concentration. The adapted mortar had a four-inch bore. The four-inch Stokes mortar could fire as fast as the three-inch mortar, had nearly as much mobility, and its shell carried almost three times as much chemical. It became a most important weapon of the gas troops of the British Army. When the United States entered the war it was adopted by our own gas troops as their standard gas weapon. It was a very effective piece for ranges from 200 to 1200 yards against small definite targets.

Following World War I, work was carried on for many years to develop a mortar which would retain all the good features of the four-inch Stokes mortar and would have increased range and greater accuracy. It was known that if the awkward end-over-end tumbling flight of the shell could be smoothed out so that the shell would bore through the air

like a rifle bullet or a gun shell, the range could be nearly doubled. The 4.2-inch chemical mortar, now the principal weapon of chemical troops, is the result of this development.

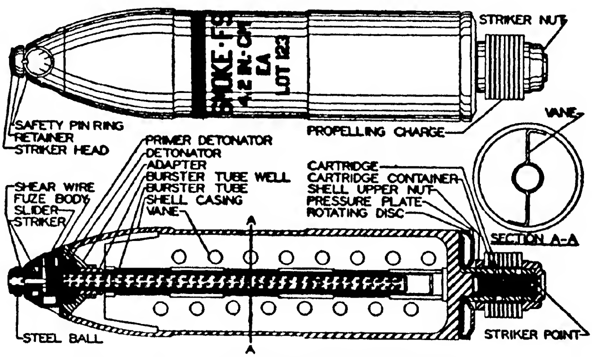
The 4.2-inch chemical mortar is a muzzle-loading, rifled, high-angle weapon which fires a high-capacity shell with the accuracy of an artillery piece at ranges from 600 to 4400 yards. For sustained fire it can deliver five rounds per minute



THE 4.2-INCH CHEMICAL MORTAR

for an indefinite period. For short periods a rate of thirty rounds per minute can be obtained by trained crews. It is mobile and can be moved forward at the same rate as the infantry advance. It is low in silhouette, being only three and one half feet high when installed, and can be concealed easily. It can be fired from small gulches, shell holes, or from behind steep ridges or buildings. Within its range it is a particularly suitable weapon for the support of attacking troops either with smoke, gas, or explosive. The desired range is obtained by varying the elevation of the piece and the amount of propellant charge.

The mortar consists of a barrel, a standard, and a base plate. Its equipment includes certain spare parts and accessories for its installation and maintenance, and a two-wheeled, rubber-tired, hand-drawn cart for transportation and combat. A sight is provided for laying the mortar to obtain the desired range and direction. When chemical troops organized according to the old tables make distant movements, the mortar, loaded on its cart, ten rounds of ammunition, an ammunition cart, and the personnel of the mortar squad are transported



SHELL, 4.2-INCH CHEMICAL MORTAR

on a light cargo truck. The barrel complete weighs ninety-one pounds. The standard weighs fifty-three pounds. The base plate is the heaviest part of the mortar, weighing 155 pounds.

The mortar shell has thin walls and large capacity, and was designed especially for firing chemical agents. It weighs approximately twenty-five and one half pounds ready to fire and holds six to eight pounds of chemical. It is prepared for firing by inserting a cartridge into its base and placing on the cartridge container rings of powder, the number depending on the desired range. When the shell is loaded into the

muzzle of the mortar it slides down to the bottom of the barrel where the cartridge is ignited by the striker pin. The cartridge then ignites the rings. The explosion expands the plate at base of the shell so that the shell engages in the rifling of the barrel, thereby giving the shell a rotating flight. Inside the shell is a perforated steel vane which causes the liquid filling to rotate with the shell and give the shell added stability in flight.

The 4.2-inch chemical mortar has been used with success by mechanized troops. Installed on a mechanized mount, it has the same mobility as a tank, personnel carrier, or other track-laying vehicle used by the armored units. It is especially useful to armored forces for laying smoke screens to permit advance against anti-tank gunfire, or to conceal movement to attack positions.

The chemical mortar is the most effective mobile weapon there is for firing gas or smoke within its ranges. A chemical company with twelve mortars firing at the maximum rate can place nearly two tons of phosgene on the target in less than two minutes. This is enough to put completely out of action every unprotected man in an area of nearly 250,000 square yards. Should the requirement be to lay down mustard gas, a chemical company in thirty minutes can fire six tons, an amount sufficient to produce an effective concentration on about 1,250,000 square yards. If called upon to lay down a smoke screen, a platoon with only four mortars can maintain under average conditions an effective screen across a front of 1000 yards. A single white-phosphorus mortar shell, when it bursts, covers an area of about forty yards in diameter, and will set fire to easily combustible substances or cause casualties among persons in this area. No weapon as yet developed can even approach the 4.2-inch chemical mortar in all-

around effectiveness for firing smoke and gas. It offers tremendous possibilities in jungle warfare with its powerful high-explosive and terrifying phosphorus shells.

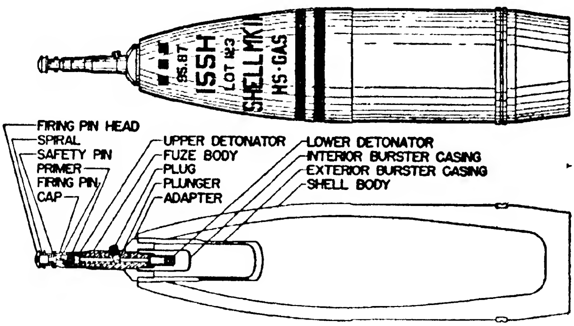
Mortar companies went into action for the first time in Sicily and immediately proved their value. The first news of the splendid initiation of these units came during the official army hour broadcast, "Enough and on Time," over the NBC Network on July 18, 1943. Lt. Colonel William Slater describing the landings on Sicily used these words, "By the time the sun rose, chemical battalions crawled into forward positions and from chemical mortars fired shells to lay down the initial smoke screen. Our early success at this important moment was due, in large part, to the effectiveness of this smoke screen." Reports and personal letters bear out the fact that the chemical battalions played an important part in that campaign and later in Italy and rendered splendid service in supporting the infantry with phosphorus and high explosive.

New tables of organization for the motorized chemical battalion call for a much more mobile and effective unit. The new mortar squad has a sergeant squad leader, corporal and six privates. The sergeant and five men, the mortar, forty rounds and equipment are transported in two quarter-ton trucks (jeeps or peeps) and quarter-ton trailers. The first jeep carries the squad leader and two men (the mortar crew) and its trailer carries the mortar, hand cart and eight rounds. The second jeep carries three men (ammunition crew) with eight rounds and its trailer carries hand cart and twenty-four rounds. A personnel carrier in each platoon will transport squad members not riding in jeeps and also the platoon overhead. The well-known cross country ability of the jeep makes it possible to transport the company practically any place where troops can operate.

For amphibious operation the mortar squad can easily be carried with jeep and trailer on landing boats so that it is available for instant use in covering the infantry advance to secure the beachhead. The weapon may be mounted on the landing craft and support the actual landing with smoke. Shell containing smoke will detonate on the surface of the water and provide an effective smoke screen to permit approach to a defended beach. The mortar in such cases is aimed by steering the boat. As soon as boats are in mortar range of the beach WP shell may be fired, for combined smoke and casualty effect or HE may be used to destroy enemy field works or to cause casualties.

Chemical Artillery Shell

The use of chemical loadings for artillery was considered a possibility long before gas was used in the First World War,



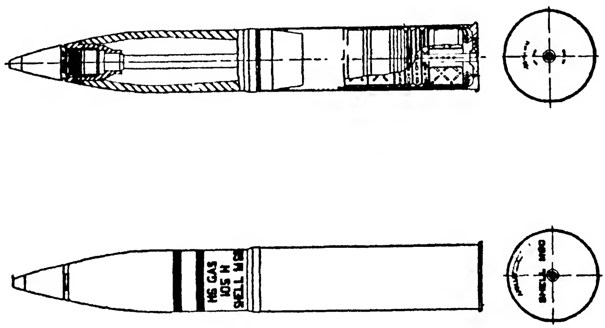
CHEMICAL SHELL FOR 155-MM. HOWITZER

and was discussed during the first Hague Conference in 1899. Tear gases were used in artillery shell before the first gas attack, and both German and French writers ascribe the

initiation of gas warfare to the other side because of the intentional or unintentional use of irritants in artillery shell.

Early attempts to use tear gas in this way did not prove successful and it was not until the French fired shell filled with phosgene in February, 1916, at Verdun that the value of this kind of munition was realized. Thereafter the use of artillery gas shell increased until the end of the war.

The introduction of mustard in July, 1917, made the artillery the principal weapon for firing chemicals.



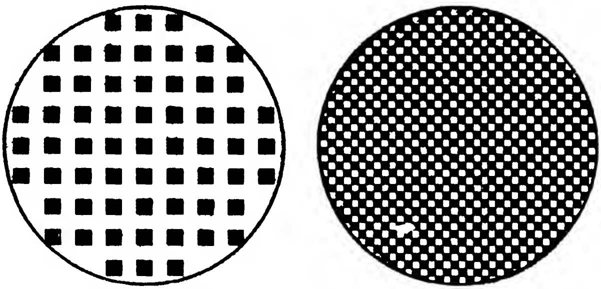
105-MM. CHEMICAL SHELL

Nearly all chemicals used during World War I were tried in artillery shell, but phosgene, diphosgene, and mustard were the most successful. By the end of the war nearly fifty per cent of German shell of all types were chemical, and the American chemical-shell ratio would have been increased from twenty per cent, the percentage which existed at the Armistice, to twenty-five per cent of all loadings if the war had continued. Mustard, phosgene, CNS, and the smokes are standard chemical artillery fillings.

Chemical shell are fired in the same way as other artillery shell from 75-mm. guns and howitzers, the 105-mm.

howitzer, the 155-mm. howitzer and the 155-mm. gun. During the First World War the artillery fired more chemical agents than any other branch of the Army.

In design the present standard chemical shells differ only slightly from the other types. Since fragmentation effect is incidental, they contain only enough explosive to rupture the



155-mm. howitzer	75-mm. gun
60 rounds	512 rounds
666-lbs. HS	666-lbs. HS
target area of 31,400 sq. yds.	target area of 31,400 sq. yds.
burst diameter 15 yds.	burst diameter 6 yds.

SHELL BURST DISPERSION

body and disperse the contents. If too much explosive is placed in the shell some chemical agents are destroyed by heat and pressure caused by the bursting charge. Also heavy charges disperse the contents so completely that casualty-producing concentrations may not be obtained. At the same time there must be enough explosive to get the agent into the air and onto the ground and not have much held in cup-like shell fragment.

The efficiency of chemical shell depends upon the amount

of chemical it carries. Therefore, the weight of filling should be as great as possible without destroying ballistic qualities, or without weakening the shell so that it cannot be fired safely. The present shells have an efficiency of about ten to fifteen per cent; that is, ten to fifteen per cent of the total weight of the filled shell is represented by active chemical agent.

In contaminating an area it is better to use a large number of small shells than a small number of large caliber shells. There are fewer holes in the pattern of mustard on the ground with the smaller shells and it would be impossible for an enemy to cross the area without getting into some of the gas. With the large shells some places are heavily contaminated while others are not hit by the agent. The diagram of Shell Burst Dispersion shows this graphically.

The gas produced close to the ground during a gas-shell bombardment follows the direction of the wind; in heavy concentrations the cloud evolved is capable of causing casualties several thousand yards downwind from the target area.

Chemical Land Mine

The peculiar characteristics of mustard type agents make them especially valuable for rendering ground unusable. If it is desired to deter an enemy from occupying or crossing a piece of ground, contaminate it liberally with mustard gas. Concentrations of H will either prevent occupation of this area or will assess a heavy penalty in casualties or labor on the force which occupies it. This is an entirely new conception in war which chemicals have brought about.

Where the place to be contaminated is in enemy territory, shells or bombs are fired upon it. Sometimes, however, in

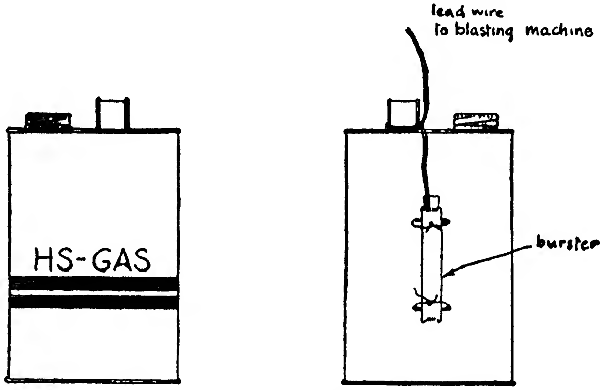
defensive situations or in a withdrawal it is desirable to contaminate ground in the possession of friendly troops but over which an enemy force must advance to reach the defender. Likely avenues of approach on the flanks of a defensive position, dry runs, valleys up which the enemy might come, offer suitable areas on which to place mustard gas.

Mustard type agents may be applied directly to an area in a number of ways. The British Gas Defense Regulations mention contamination by means of hand contamination bombs, vehicles for spraying vesicant agents, large containers fired by time fuses, and contact or delay action mines. Commandant Y. M. Fishman in the Red Army text *Military Chemistry* describes hand chemical grenades, chemical mines, and special ground appliances for the infection of an area. The latter he considers the simplest means for what he calls "infection ahead of time." These ground appliances may be carried by one man (so-called kit type), or be placed on a cart or motor vehicle. The principle of action consists in spraying the agent from the container by compressed air or by special pumps operated by hand or motor. The Italian regulations describe similar devices for what they term soil contamination.

The most satisfactory device of this kind is the chemical land mine, a container of metal or glass, loaded with mustard and provided with a charge to burst the container and release the chemical. These mines are emplaced by hand. They may be exploded individually by time fuse or connected for electrical discharge in large numbers at one time.

The United States Army has standardized a one-gallon chemical land mine. This consists of a container to hold the chemical and a burster component which comes separately. The container and burster are assembled in the field. The

mine, completely assembled, weighs about twelve pounds. Most of the weight is chemical agent. On explosion the mine effectively contaminates an area about fifteen yards in diameter when using a small burster, or about twenty-five yards when using a larger bursting charge. The container is a rectangular tin can commonly used for varnish or sirup with two soft wires soldered on the side to hold the burster in position.



CHEMICAL LAND MINE

It holds a trifle more than ten and one-half pounds of mustard gas.

The burster originally made for the mine is a paper cartridge containing pressed nitrostarch explosive. This burster is inserted in the wires on the sides of the can. It is used when the mines are fired individually with a blasting fuse. The most convenient burster when the mines are fired in large numbers by electricity is primacord, an explosive which looks very much like a piece of rope and which is flexible, light, and easily used. It is furnished on wooden spools in lengths of 500 to 1000 feet. The operation is simple. Just lay the primacord on the ground and place the mine on top of it;

then detonate the primacord with a blasting cap or electric detonator.

Mines can be used in large numbers to contaminate roads, or to establish gas barriers. They are applicable, especially, in defense and delaying action, either alone or with demolitions and other obstacles.

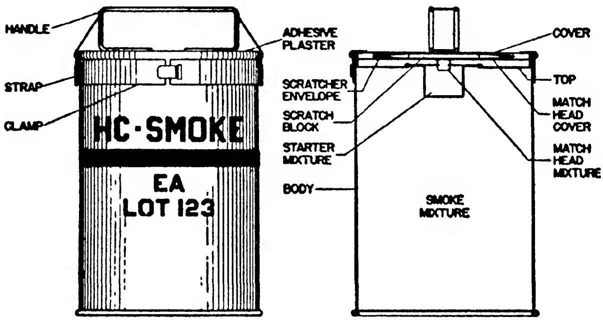
Gas mines generally are carried by chemical troops in one and one-half-ton cargo trucks, 200 per truck. One mortar squad or ammunition squad of a chemical company can install this number easily in a single operation. The time required for installation depends on the nature of the ground and the distance mines must be carried by hand. Where there is no hand carry, 200 mines can be laid, wired, and exploded in about four hours.

Smoke Candles

Smoke produced by the detonation of a bomb or shell sometimes forms an inefficient smoke screen because the force of explosion causes a large part of the smoke to be blown high into the air. The ideal smoke screen is one that resembles a fog, hangs well to the ground, and does not dissipate rapidly. To meet these requirements as well as to provide a munition that could be carried easily and used under many different battlefield conditions, a demand arose for a small compact munition which could be carried and set off by an individual. The smoke candle was the result of this demand. It found wide use in trench warfare, and when used properly under favorable conditions it is still an effective weapon. Smoke candles or smoke grenades may be used to screen movements within friendly areas, to screen river crossings, to disguise or simulate cloud attacks with cylinders, or to draw

enemy fire to unimportant places. Small forces frequently are able to use candles effectively in withdrawing from action.

There has been developed for training in our Army, a larger device called the smoke pot. This is a tin can not quite seven and three-quarter inches high and a little over five and one-quarter inches in diameter which contains HC smoke mixture, a fast-burning starter, and an ignition device of



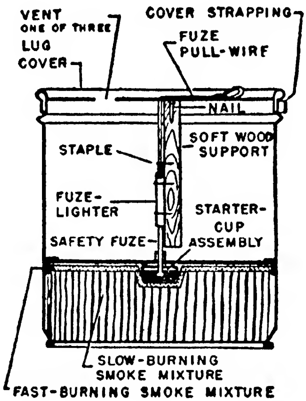
HC SMOKE POT

match head composition. A scratcher block with the same material on it that is used on the side of a match box is provided to light the match head. The match head starts the fast burning compound which ignites the HC smoke mixture. The smoke reaches maximum production in about twenty seconds, and the smoke pot continues to burn for some six and one-half minutes. Although originally intended for training, this device has been found useful for producing smoke screens quickly over large areas, especially in connection with the Mechanical Smoke Generator M1. A larger pot (32-35 pounds) has been developed for the latter use.

Floating Smoke Pot

A still larger device is the HC floating smoke pot, designed to fill the need for a floating smoke munition. It is lighted and dropped off the stern of a landing barge or speedboat. Also special racks have been built so that both types of smoke pots can be burned in the stern of landing craft. These munitions proved of great value for screening landings on Sicily in July, and Salerno in September, 1943.

The HC floating smoke pot, M-4, is also valuable along



FLOATING SMOKE POT

waterways where artificial concealment is required. The same considerations govern its use as in the case of all static smoke munitions, supplemented by the effect of tides and direction of current. When dropped in the water near shore lines and along rivers, the smoke pots bob to the surface and burn

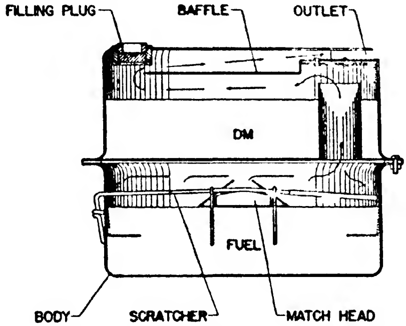
despite their immersion. About three-fifths of the pot rides below the surface and approximately five inches above the water. The pot is a cylindrical steel pail of 5-gallon capacity, 13 inches high and 12-1/16 inches in diameter. Three vents in the cover permit the smoke to escape. The fuel consists of three mixtures—the starter, a fast-burning mixture, and a slow-burning mixture. The starter is composed of silicon, potassium nitrate, iron oxide scale, charcoal, and aluminum. The two burning mixtures comprise hexachlorethane, zinc oxide, and grained aluminum. The proportion of grained aluminum varies the burning.

Irritant Candles

When the Germans introduced sneeze gas (DA) in July, 1917, they fired it in artillery shells which they marked with a blue cross. A bottle of the DA was embedded in high explosive within the shell. These Blue Cross shells dispersed the DA by explosion. The particles of sneeze gas that were produced by the explosion were relatively large and were easily removed from the air by filters which soon were placed in all gas masks. At about the close of the war it was learned by our experts that if the irritant agent were heated or if hot gases from burning powder were passed across it the sneeze gas would be vaporized and pass into the air as an extremely fine cloud of particles which would penetrate filters of any but the very best gas masks. Moreover, in this finely divided state the agent had a much more powerful effect on the body.

As a result of their research the Irritant Smoke Candle was developed. It is an effective weapon when it can be used properly but like the cylinder its use is dependent on wind and weather. Fired statically, in or close to front lines concentration of gas is greatest where least desired.

The Irritant Candle consists of two cans each seven inches in diameter and not quite three inches high bolted together one above the other with an asbestos gasket between. The bottom one contains a cake of smokeless powder fitted with a wire ignition device which permits drawing a scratcher of matchbox composition over a matchhead in the center of the powder. A small circular flue is the only opening between the bottom and top compartments. The top can contains a



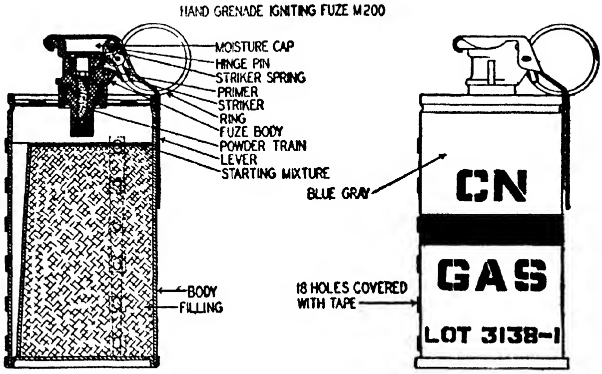
IRRITANT SMOKE CANDLE

two-pound cake of DM. The heated gases from the burning powder in the lower can pass closely over the surface of the cake of DM and vaporize it. The candle burns three or four minutes and produces a heavy canary yellow cloud with a smoky odor which is extremely irritating. The smoke is so fine that it will pass through the ordinary gas-mask filter. The army gas mask will remove it. This weapon has never been used in war. If used it would be necessary to fire large numbers under favorable wind and weather conditions.

Grenades

The exact time the grenade was first used in war is uncertain, but it is known to date back many centuries. Up to

the close of the eighteenth century soldiers were regularly trained in throwing hand grenades, and were called grenadiers. Then for a century grenades went out of fashion. Their use was again revived by both sides in the Russo-Japanese War. In the First World War the grenade was a regular part of the equipment of all infantry soldiers.



TEAR-GAS HAND GRENADE (M-7)

Grenades containing smoke and incendiaries are especially useful for small screening operations and also for casualty effect on personnel in small centers of resistance such as machine-gun nests. Chemical grenades have found wide use in war and in peacetime training. During World War I the phosphorus rifle grenade was an extremely valuable and effective weapon. It is no longer standard, but the demand for chemical rifle grenades may bring them back into use in the present war.

Grenades can be thrown by hand a maximum distance of thirty-five yards, but the average soldier probably attains a distance nearer twenty-five yards. These munitions may be dropped from fast moving vehicles such as armored cars or tanks either by hand or by a simple dropping mechanism.

The usual mixtures in burning type chemical grenades are either tear gas and smokeless powder, as in the CN grenade (M7) or a mixture of tear gas and DM (Adamsite) and smokeless powder, as in the CN-DM grenade (M6). The powder provides the heat which vaporizes the chemical agent and gets it into the air. There is also an HC smoke grenade (AN-M8). This is really a small smoke candle with a grenade firing mechanism. A thermate grenade M14 has also been developed. It is a useful incendiary and has much value in destroying ordnance. The WP smoke grenade M15 is a bursting-type hand grenade useful for mopping up, and for casualty and incendiary effect as well as for screening. It has a four-second fuse. It has found wide use in battle.

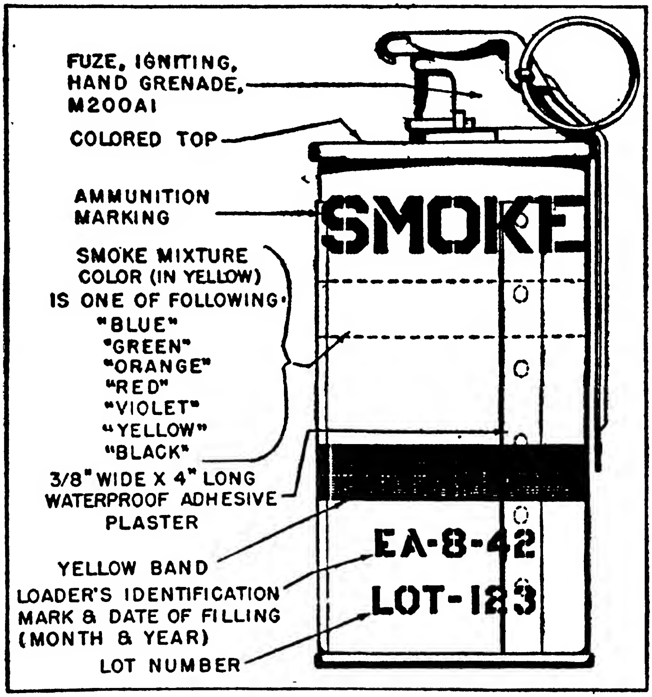
Irritant chemical grenades are timed to ignite in two seconds since their major use is in riots and in other civil disturbances. Earlier types had five-second time fuses.

The most recent development is the colored smoke grenade (M16) used for signalling and for identification. Several vivid colored smokes are available. By using a previously agreed upon color, ground forces may make themselves known to friendly aircraft. The intense yellow, blue, orange, violet, black, green, or red smokes are easily distinguished at high altitudes. Some of our forces in North Africa were provided with these colored grenades and they are becoming increasingly valuable as new uses are developed. They are especially useful for signalling between armored elements and aircraft.

There are a great many different types of chemical grenades which are manufactured by civilian concerns. Some of these are fired from gas guns. Many of them are equipped with some means which prevents them from being picked up and thrown back.

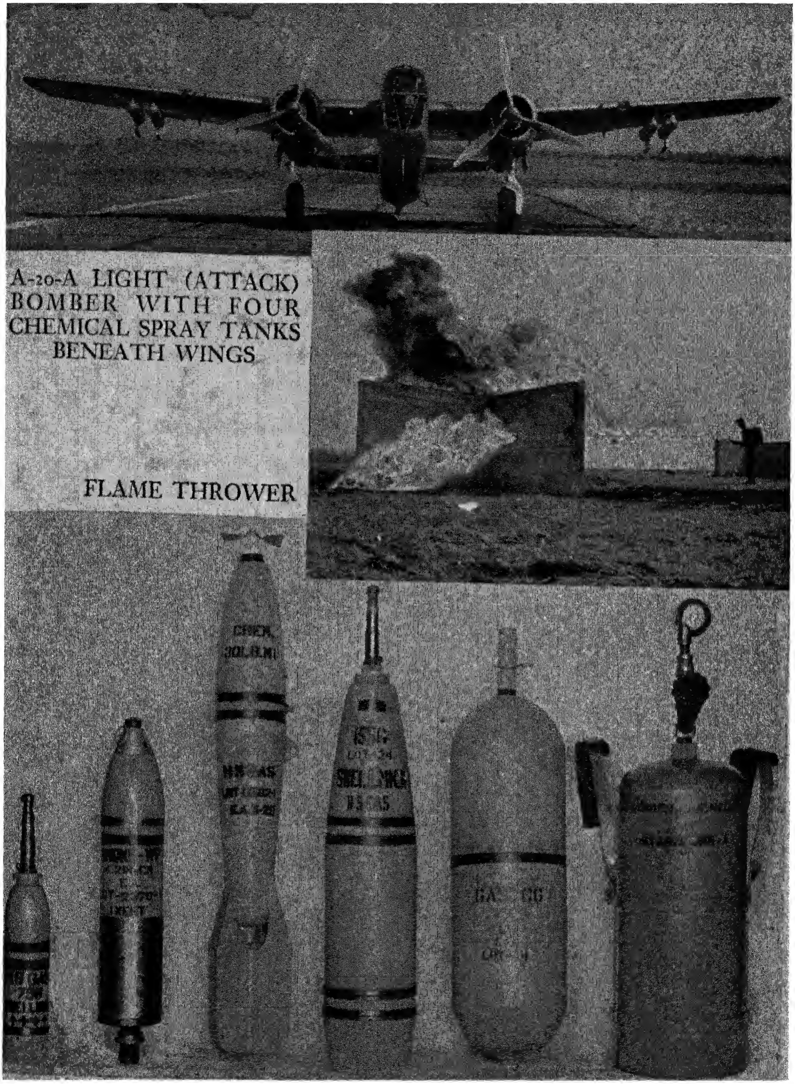
A crude type of grenade, but one which proved very

effective during the Spanish Civil War and Russo-Finnish War, and which is being used successfully in the present war, is the Molotov Cocktail. This is simply one or more bottles filled with gasoline or kerosene, and sometimes tarry material, and wrapped with cotton waste. It is thrown against the side or top of a tank or other armored vehicle. An ignition device



COLORED SMOKE GRENADE

may be combined with the bottle and the waste so that the contents burn as the bottle breaks, or the inflammable liquids may be lighted by throwing an incendiary grenade against



A-20-A LIGHT (ATTACK) BOMBER WITH FOUR CHEMICAL SPRAY TANKS BENEATH WINGS

FLAME THROWER

CHEMICAL MUNITIONS

Left to right: 75 mm gun shell H gas; 4.2″ chemical mortar WP smoke shell; 30 lb chemical bomb M1 H filled (now obsolete); 155mm gun shell H gas; livens projector phosgene shell; portable chemical cylinder M1.

the surface already covered with combustible material. All that is necessary is to break a bottle of gasoline against the metal sides or top of the tank and then set fire to the gasoline.

There are many combinations of this idea which can be improvised by soldiers or partisans from whatever they have at hand. Tar is added so that the liquid will not run off the sides of the tank quickly. When more elaborate means are not available, the man throwing the "cocktail" generally lights the gasoline saturated cotton waste surrounding the bottle before he throws it.

The "Molotov Cocktail" is perfectly adapted to guerrilla fighting. It has found wide use against tanks moving through cities or heavily wooded country. A box of a dozen or two dropped on a tank from a second-story window is guaranteed to bring the crew out of the tank in record time. To be really effective they should be used in fairly large numbers and against both sides and top of the vehicle.

Glass or frangible grenades made to hold highly poisonous volatile compounds have been used by Germans and Japanese. These are not new as they were used in the First World War by the Germans to disperse tear gas. Their present use is principally against tanks. We have the frangible grenade M-1 with various fillings. It is a pint glass bottle which has an igniter attached when filling is incendiary oil.

Tank Devices

Artillery and anti-tank guns are the most dangerous enemy the tank has to cope with on the ground. Successful operation of tanks requires that these guns and their ground-observation posts be blinded by well-placed smoke. The value of smoke screens in assisting tanks to accomplish their mission has been amply demonstrated in action. Officers of

tank units insist that smoke is an absolute necessity for tank operations, that tanks must be equipped with some device for laying smoke themselves and also should have special smoke units to support them.

There are a number of different devices at present in use for producing smoke from tanks. The simplest is the exhaust smoke producer. This is a simple apparatus which permits the driver to inject crude oil or chemical into the exhaust manifold of the vehicle, which may be tank, truck, automobile, or even motorcycle. The great heat in the exhaust manifold vaporizes the smoke material which pours from the exhaust in a heavy cloud. The purpose is to produce a large puff of smoke behind which the tank for example may gain protection for a few moments if it suddenly runs into anti-tank gun fire or otherwise gets into trouble. It is not a cure-all and would not ordinarily be used for laying a continuous screen since by doing this it might merely outline its own path for the hostile gunner. However, if a vehicle is proceeding up a road and runs into trouble, it can turn quickly, eject its smoke in two or three large puffs, and get away or decide what further action to take. Tear gas may be added to the smoke without difficulty.

Bootleggers made use of a device such as this in the prohibition era. They used it to eject smoke behind them as they tried to outrun the "revenuers" or the police. The police car, running into the smoke, had to reduce its speed and creep along. The bootlegger car could continue at full speed, and according to news reports a great many of them escaped in that way along the Washington-Baltimore-Philadelphia Highway, where it seems to have found its greatest use.

Another device which has wider application is a small

smoke mortar or grenade thrower. With a weapon of this sort the smoke is thrown a few hundred yards away from the tank in the direction of the source of danger. Thus there is no chance of the smoke itself becoming an aiming point as is the case when the exhaust type smoke is improperly used. At least two different smoke mortars of this nature have been used successfully in the present war. One is a muzzle-loading device fastened to the outside of a tank which throws a smoke grenade a distance of two or three hundred yards. It has the disadvantage that in order to fire it a man has to reach outside the tank and drop the smoke grenade or projectile down the muzzle from which it is projected by a shotgun cartridge. The other is a breech-loading, two-inch mortar, which fires a small smoke munition for distances up to seven or eight hundred yards. It may be fired from inside the vehicle, the muzzle being pointed out through a port. It has proved very satisfactory. Some such weapon is important for emergency use by armored vehicles. Large smoke screens cannot be produced by any small-caliber mortar but sufficient smoke is developed for purposes of retreat. It is surprising how small a haze will prevent accurate fire. Thick smoke is not only unnecessary but may be undesirable.

In addition to the small weapon a proportion of the tanks may carry a larger caliber mortar for laying large smoke screens. A tank mortar which proved to be most successful in Europe during the German drive through France was a weapon of slightly larger caliber than the four-inch mortar, with a range of better than 2000 yards. Experience indicates that a certain proportion of the tanks in a unit, say one out of every four or five, should have this large-caliber smoke mortar; or armored regiments should have attached for their support chemical mortar platoons mounted on track-laying

chassis and ready at all times to lay down fairly large screens at ranges up to the limit of the mortars.

Foreign writings, especially Russian and Italian, have described means of contaminating ground with mustard gas from moving vehicles. These devices include mine layers and mustard-gas spray tanks in which the pressure is supplied by hand pump or motor-driven pump. In the former case, mustard-gas mines with time fuses are dropped from the rear of the vehicle automatically or by hand. It is quite possible that vehicles of armored forces will be used to disperse chemical agents. Their ability to move fast and cover long distances will make it possible for a commander to contaminate areas on a flank or in any dangerous direction over which he expects an enemy to proceed.

The Flame Thrower

Sensational reports credit German Flammenwerfer units with great success during their drive through the Low Countries and France in 1940, especially in the capture of concrete emplacements and fixed defenses that had resisted bombardment with high explosives and appeared otherwise invulnerable.

The Army has a portable flame thrower which may be used by chemical troops and engineer troops. This device can be carried easily by one man. The fuel is diesel oil or gasoline. The latter may be treated to increase the consistency. Pressure is provided by a small tank of compressed air or nitrogen. A small tube of hydrogen or propane gas is attached to the fuel tank. Flame is started by igniting the gas by means of an electric spark or burning-type cartridge. The burning gas ignites the oil. The flame is effective for a distance of about

fifty yards in the latest models. A larger flame thrower is developed for use on tanks. This one has a much greater range. Range depends on the distance that the oil can be thrown before it is broken up into a fine spray or consumed by burning. By increasing the consistency of the fuel much greater ranges obviously are possible, but flame is reduced.

Judging from description of German attacks with the portable flame thrower in France in the present war, it is quite likely that the organization described during the First World War is somewhat similar to that used at the present time.

Translation of a German document captured during the past war gave the organization of a flame-projector detachment and a brief note as to the method of using. The detachment which apparently was a part of a larger unit, doubtless pioneer engineers, had a strength of one officer, nine non-commissioned officers, and thirty-four men. Besides carriers for the projectors and nozzles, a number of machine gunners were included as an organic part:

> Employment: The flame projectors precede the assault troops. If the enemy resists, the men carrying the projectors halt and lie down, and the attack detachment advances and makes use of its grenades; the two groups act alternately.
>
> They are useful in combats against villages. They must fight in close liaison with the infantry, which helps them with the fire of its machine guns and grenades.

This resembles methods now employed by all armies. The ground assault on a concrete emplacement or pill box is preceded by heavy bombing or artillery fire. Close behind this bombardment the engineers and infantry approach with wire cutters, grenades, and heavy explosives supported by smoke

and strong machine-gun and rifle fire. When a breach is made in the wire and other barriers surrounding the pill box the flame thrower detachment rushes in and from a position either above or below, but in any event close in, directs flame against the openings and sides of the emplacements.

Japanese troops used flame throwers to subdue the fortifications of Corregidor according to a Japanese commentator broadcasting from Tokio on May 14, 1942. He described a photograph in the Tokio newspapers of that day and said that "it showed that the Japanese chemical units blasted one of the concrete fortifications with sprays of shooting flames."

Again, at Guadalcanal, the Japanese used flame throwers during the bloody fighting at Raiders Ridge. Corporal John J. Conroy is quoted as follows in a UP dispatch, March 4, 1943: "In the Ridge battle, the night was continually pierced by screams, followed by the weird, savage shout, 'Banzai.' Somewhere on our right flank in the vicinity of the raiders' lines there would come a flash of light—then the screams. The Japs were using liquid fire. But it only made us fight harder afterward—to the Japs' sorrow. That place ain't called Bloody Knoll for nothing."

We also have used the weapon against the Japanese. Another UP dispatch, this time from Allied Headquarters, July 31, 1943, says: "Sweating American soldiers, jamming their heavy equipment through jungle growth under the cover of tanks and planes, turned flame throwers on the south flank of the strong Japanese positions around Munda yesterday, and inland their comrades beat off an enemy counterattack. The Americans directed blasts of flame against the gunports of the deep Japanese pillboxes which have reduced the American advance to a yard-by-yard struggle."

The portable flame thrower seems to have found a place

in a carefully organized attack on a strongly fortified position. For clearing dugouts, trenches, emplacements, or any confined spaces, it is a useful and time-saving weapon. Against tanks it presents very interesting possibilities if some means can be found of getting the machine within range of the tank to be attacked. There is no question concerning the power of the tongue of flame if it can be brought close enough to the target. The difficulty is bringing the two together. On the offensive, a strong shield must permit the man or the flame-throwing machine to get near enough to the defender to dislodge him. This shield may be fire power or armor, but whether it is bullets or armor plate it must be present. Otherwise, the defender is going to stop the flame thrower by his own fire before it can get within the short distance to which it must approach to be effective. On the defensive, it may be useful for the close-in defense of important points. Fixed or emplaced flame throwers may be used to protect narrow defiles, important stretches of beach, bridges, or any place where an enemy must assault directly on a narrow front. Size and fuel supply are not a serious barrier in the case of this stationary equipment. Here again it must be heavily armored lest enemy explosives strike it and spill the inflammable oils where they will burn up that which they were intended to defend.

IX

AIR CHEMICAL WEAPONS

WHEN the full power of air chemical warfare is revealed, the orthodox military mind will receive as great a shock as was caused by the success of German mass attacks with tanks and airplanes, or the Japanese air assault on Pearl Harbor with its final proof that airplanes can actually sink battleships. During the First World War chemicals were never used from airplanes. Today every world power is able to use the air chemical weapon. There is no doubt that the airplane provides the most effective method for disseminating the mustard type agents, and large-scale dispersion of mustard gas or Lewisite from the air will cause a complete revision of tactics and strategy.

The Italians used mustard gas from the air in 1936 in Abyssinia but the results were dismissed without much comment since the attacks were made on unprotected and untrained tribesmen, and heavy casualties were inevitable. These attacks, however, were made on a relatively small scale, were completely successful—an entire army was routed. They give a foretaste of what is likely to happen in the future.

The problem of protection against gas is tremendously complicated by the airplane; no longer will there be any areas where anti-gas measures are unnecessary. During the First World Wai gas never penetrated more than ten or

twelve miles behind the front lines. Today the wide radius of action of aircraft and the development of extremely effective means of projecting chemicals from airplanes have introduced possibilities that radically change the entire aspect of chemical warfare. The movement of troops and supplies in rear areas is especially vulnerable to aero-chemical attack. Gas is the ideal weapon for causing confusion and delay. Industrial installations and transportation centers subjected to a combination of chemical and explosive attacks are faced with a problem which is difficult to solve.

Chemicals may be placed on a target from the air by chemical tanks from which the agent is dispersed in large drops from high altitudes, or as a fine spray or mist from lower altitudes, or by chemical bombs which may or may not contain a bursting charge.

If it is desired that the chemical fall to the ground in fairly large drops from high altitudes, it is necessary to force the liquid out of the tank to the rear at a speed roughly equal to the air speed of the airplane. This makes it drop straight down. Unless the liquid is expelled by force it is broken up by the air stream created by the fast-moving plane and so completely atomized that it hangs in the air as a fine spray and drifts for miles with the wind.

If a large area must be covered in a short time with complete surprise, and the attack may be accomplished from low-flying airplanes, the liquid may be released without internal pressure. In this case the agent simply runs out when the discharge line is opened in flight, is broken into a fine spray by the blast of air and falls the short distance to the ground like rain or mist.

Two types of apparatus have been developed to accomplish these purposes. Both are normally carried on the bomb racks

of an airplane. The one which uses pressure is called the pressure or sprinkling type. The other, for low-altitude attacks, uses the air blast of the fast-moving plane to break up the liquid and is called the spray type. The pressure apparatus may provide a method by which gas can be dropped from fairly high altitudes or at extremely high speeds.

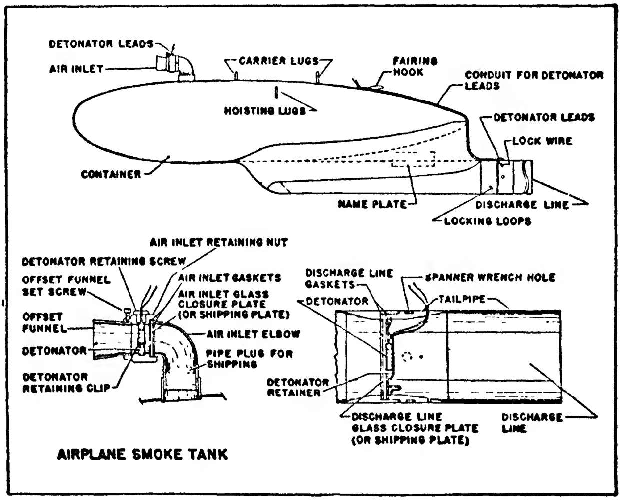
The sprinkling type apparatus is comparatively heavy for the weight of active agent it carries. On account of this weight it is most suitable for medium or heavy bombardment airplanes. Mustard type agents, tear gases, and liquid smokes may be used in the sprinkling apparatus. It is difficult to predict where the drops will fall when the tanks are discharged at high altitudes for the fall depends upon the speed and direction of the winds at the various levels. Under favorable air conditions at night it might be possible to hit a target such as a large industrial area from altitudes up to 10,000 feet. At altitudes of 2000 feet it should not be difficult to hit with accuracy a small area such as a railway terminal or junction. The width of the area covered increases with the altitude from which the chemical is projected and also with the wind velocity. The more area covered, however, the less will be the concentration of the agent used.

There is a possibility that air chemical attacks may be made from such a height and distance that the aircraft cannot easily be detected at the target. The tremendous importance of this possibility is clear. The only protection against it would be a protective suit continuously worn enclosing a man from head to toe. Perhaps we shall return to full armor; not that of the knight armed cap-a-pie, but an armor that will resist molecules rather than lances.

The spray type apparatus used at low altitudes is the standard method for dispersing liquid chemicals from the air and

is probably the most effective of all the means we have for disseminating chemicals when its use is practicable.

The airplane spray tank (M10) is simple and light while the sprinkling apparatus is complicated and heavy. The spraying equipment for a light bombardment airplane consists of four tanks fastened to racks underneath the wing. The tank



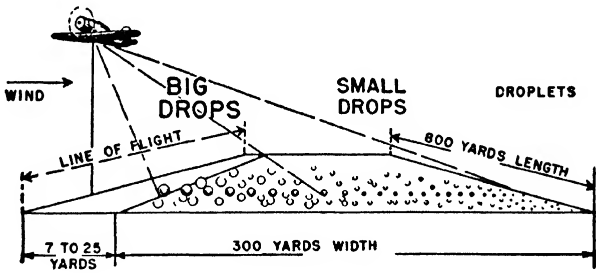
AIRPLANE SMOKE TANK (M10)

holds about thirty-three gallons of liquid. It weighs sixty-eight pounds when empty.

When the discharge line is operated in flight by electrical means controlled by pilot, the chemical runs out the vent and is broken by the air blast into a finely atomized cloud of droplets. These droplets fall to the ground forming a rectangular pattern. The larger drops fall almost underneath the plane while the small ones are carried further down wind. The length of the pattern is the distance that the airplane has

travelled during the time the tank was being emptied. The higher the airplane and faster the wind, the wider the pattern. A wind perpendicular to the line of flight will give a wider pattern than a wind that is parallel. The best conditions are altitudes of fifty to one hundred and fifty feet, and a wind speed of five to fifteen miles per hour. Under these conditions an area about a half mile long by nearly a quarter mile wide may be covered by one tank.

The entire area covered is contaminated by the vapor and droplets of chemical. Since the chemical agent has been finely atomized, evaporation is rapid by this method and the immediate concentration of gas in the air is greater than would be the case with shell or bomb. The concentration of gas obtained in the air by spraying is greater than that



FALL OF LIQUID—AIRPLANE SPRAY
Light spray effective over much greater width.

obtained by any other weapon. Moreover, the effects are produced more quickly and the toxic possibilities of the agent are more completely realized. The agent is much less persistent, however. In the summer, on ground which is not wooded, troops can usually enter with safety a sprayed area within twenty-four hours if care is exercised. The vapor at the time of spraying and for some minutes afterwards will

affect all personnel in the actual contaminated area and even for a distance down wind at least equal to the width of the area sprayed.

Attack aviation is particularly suited for the dispersion of chemicals. Its low-flying tactics allow it to place the chemicals on the target accurately. By using one or two tanks at a time, per airplane, it is possible to control the amount of contamination. If an extremely heavy contamination is desired all four spray tanks can be discharged at the same time, and for increased effect chemical bombs may be used in place of the fragmentation or demolition bombs which generally are dropped while spraying.

The velocity of the wind may determine the altitude of flight, but normally planes will be flown as low as possible and in this way get a heavy concentration on the target. Chemicals work as well at night as in the daytime—all that is necessary is to get the gas on the target.

There has been much speculation and debate as to the ability of ground troops to shoot low-flying attack airplanes out of the air. The argument has never been settled as none of the warring nations have employed specially designed high-performance airplanes for low-level flight according to the methods which were developed in our air force.

During the Spanish War low-level attack was attempted by slow airplanes which failed to take advantage of cover and which were shot down when caught in a valley by fire from hillsides. Conclusions were drawn from this that low-level flight is unduly hazardous. Regardless of hazard there is no more effective method of attack against personnel or airplanes and tanks on the ground and it will be used. It was this type of attack that the Japanese used against Wheeler

Field and Hickam Field, and with torpedoes at Pearl Harbor. There have been many reports of successful low-level attacks by the Germans, the Russians, and the British, but the more spectacular, though perhaps not more effective, Stuka dive bomber has received most of the notice.

The United States Army Air Corps pioneered in attack aviation and for many years led the world in the development of low-level attack equipment and methods. As a matter of fact, low-level assault on ground troops is spoken of in Europe as "the American method," or "American Attack." The theory of this form of attack is that flight at altitudes of about seventy-five feet, following the contour of the ground and coming in for the assault at an unsuspected angle, gives all the advantages of surprise and concealment from the enemy. This surprise, combined with high speed and powerful fixed machine-gun fire which sweeps 1000 yards ahead of the plane, permits the airplane to approach the target, deliver its blow, and get away without being subjected to effective fire from the ground. The low flight prevents the use of large-caliber anti-aircraft artillery guns. The low flight and high speed make it difficult to track the plane with machine-gun fire. Random shots from rifles fired by large numbers of soldiers provide the greatest danger to the low-flying attack airplane. Enemy pursuit aviation is less effective so close to the ground.

In spite of its great promise, the fact that attack aviation had not been used to any great extent in Europe and an exaggerated and possibly groundless fear of vulnerability to ground fire led us to concentrate for a while on the development of a form of gliding or diving attack from higher altitudes. The method we pioneered, however, is returning rapidly to its proper place. Each day brings increasing indica-

tions that the American method of low-level attack is now in wide use on all fronts.

Chemical spray is practical and is a powerful weapon at higher altitudes but is not as accurate as at seventy-five to one hundred and fifty feet. The initiation of gas warfare will bring low-level attack increased importance, for the possibility of chemical spray will remove the danger of effective ground fire. The rain of mustard gas will deter most ground soldiers from firing at the hostile airplane until they have first adjusted their gas protection—when it will be too late.

The airplane bomb provides another effective means of disseminating chemical agents and where contamination of an area for long periods with persistent agents is required, the chemical bomb is more useful than the spray. The combination of high-explosive bomb and chemical bomb is an extremely efficient team when the mission is to destroy and prevent rebuilding. A well-placed demolition bomb on a railroad center will cause great damage; much time will be required to effect repair. Add a few mustard bombs and the time required to make the repairs will be increased many times. Working in a contaminated atmosphere is possible only when wearing protective equipment. It takes about three times as long to do a job when wearing a gas mask as without the mask.

At the present time the 100-pound bombs, M47 and M70, are the standard chemical bombs provided for our air force. Until the war the 30-pound M1 was the standard, but it is now obsolete. The 30-pound M1 held only about nine pounds of mustard or 12½ pounds of smoke. Thus, only one-third of its weight was active chemical.

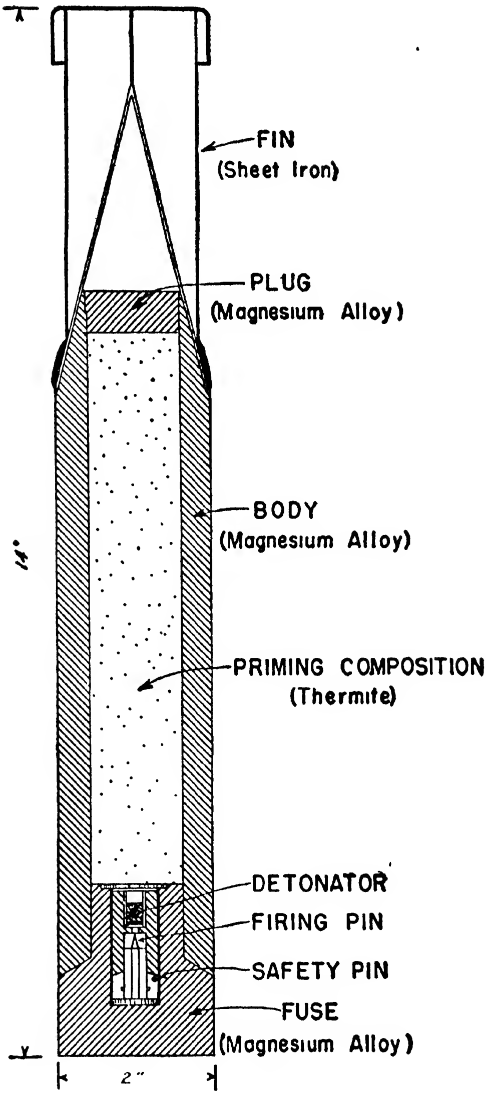
In searching for a more efficient bomb, it was found that

a tin can filled with mustard gas, dropped from low altitudes at high speeds, gave excellent dispersion of the liquid mustard. Such a device was almost too simple for the bomb expert to accept, however, and there has been developed the chemical bomb M47, nearly three-fourths of which is active chemical It holds 71 pounds of mustard gas for an overall weight of 100 pounds. A later bomb, the M70, is somewhat heavier in construction. It weighs about 115 pounds and carries a little less than 60 pounds of mustard gas. The M47 may be dropped from the 500-pound bomb racks of an airplane in a cluster of four bombs. They also may be attached singly or in pairs to bomb shackles by cables so as to fill entire bomb bay, an efficient load.

Unless the burster is used when the bomb is dropped from high altitudes, much of the mustard is lost by the bomb burying itself in the ground. A super-quick fuse and small bursting charge, however, assure a burst on the surface of the ground and scattering of the contents over an area of 25 or 30 yards. To be quite fair it must be admitted that the bomb expert has justified the substitution of the specially designed bomb for the tin-can bomb by preventing the bomb from burying itself.

When flying is done at low altitudes the tin-can bomb still has much to recommend it. It is simple, cheap, and effective. The dispersion of the contents is obtained by the tin can breaking up on contact with the ground. This method gives excellent distribution of the chemical and prevents any damage to the plane from flying fragments.

Where gross contamination in a small area is desired, for example a bridge or rail junction, the 100-pound bomb is highly effective. This bomb scatters the chemical over a radius of about 40 yards.



TYPICAL INCENDIARY BOMB

Large-size (500- to 1000-pound) chemical bombs will prove an effective means of disseminating powerful non-persistent agents since high concentrations can be set up in a short time.

The small incendiary bomb is one of the most important of all munitions. Hardly a bomber takes off on a hostile mission today without some share of its load being taken up by incendiaries. The most widely used incendiary is the small magnesium bomb, the entire casing of which is consumed by burning. The Germans have one weighing a kilo (2.2 pounds), their "electron" bomb, and the British have one that weighs about four pounds. We have developed a four-pound magnesium bomb, the M-50, which is being used effectively and in large numbers by our air forces.

The typical small incendiary bomb has a body of magnesium alloy and sufficient thermite or similar filling to burn intensely and ignite the magnesium body when fired by a simple impact fuse. These little bombs are generally dropped in clusters or bundles or within a larger bomb case which opens in mid-air. The Finns and Russians call the latter device the Molotov Bread Basket. The M-50 is carried on the 100-pound bomb racks in a cluster of 34 bombs and on the 500-pound racks in a cluster of 128 bombs. The small bombs are scattered by this means over a wide area. They burn fiercely upon landing; since they develop a temperature of over 3,000° F., they will ignite anything combustible with which they come in contact.

A four-pound thermite bomb has been used as a substitute for the magnesium bomb. This bomb has a thin steel jacket filled with a special thermite mixture. It develops a higher temperature than the magnesium bomb, about 5,000° F., but burns out more rapidly. It is especially useful against metal

material such as machinery or storage tanks, because of the intensity of heat developed. This is the bomb that the Japanese report was used in the Doolittle raid on Tokio.

The M47 100-pound bomb filled with thickened gasoline provides a larger-sized incendiary. One of the best fire bombs produced up to 1944 it has been used in large quantities and most effectively by our Air Force.

A small oil bomb which can be carried in large numbers has proved very effective against many targets and is the most recent development. This munition, incendiary bomb M69, weighs about six and one half pounds, carries a thickened gasoline load, and is dropped in a 100-pound cluster of fourteen bombs or a 500-pound cluster of sixty. The scientists of the National Defense Research Committee and the Standard Oil Development Company cooperated in the development of this munition. It is a base ejection bomb which throws out the ignited mixture in a blazing mass so that it is more likely to hit a combustible surface than the magnesium bomb which burns where it falls. It burns for over ten minutes and develops a great quantity of heat. Loaded with phosphorus the small base ejection bomb is a very effective smoke producer with some incendiary value.

Auxiliary explosive charges are added to incendiary bombs to prevent putting out the fire. Timed to explode at differing intervals, two to six ounces of TNT act to discourage the air-raid wardens. The charges are so arranged that they do not themselves extinguish the fire.

The purpose of chemicals dispersed from the air is to create casualties; to contaminate areas, such as airdromes, avenues of approach, and important ground, and deny their use, to contaminate material, such as airplanes, bombs, ammunition, and food; to threaten hostile personnel and equip-

ment and thereby delay operation and require that personnel and equipment be provided with protective means and decontamination facilities; or to cause damage by fire.

In the neutralization of hostile airdromes or the contamination of an area, the threat of casualties should cause the enemy to avoid that airdrome or area. Once an enemy has experienced a heavy concentration of persistent gas he will hesitate to operate from or in contaminated areas in future operations.

On a hostile airdrome it may be possible to contaminate the ammunition and bomb supply as well as the airplanes. This will slow down operations, since impervious gloves and protective clothing must be used in loading, servicing, and maintaining the planes. This applies to the ammunition and food supplies of the ground arms. Food that has been exposed to persistent chemicals must be thrown away. The airplane offers a new field here for the chemical agent. Most chemicals used in the First World War were dispersed by cylinders or by ground weapons. The added range afforded by the airplane makes the dumps of food and ammunition and material in rear areas an attractive chemical target.

The threat of a chemical attack by air is in itself a powerful thing. Even in the rear areas the troops must constantly have the gas mask available. This applies even to places in the interior of the country. Anywhere that a bomber can reach there is danger of gas, and troops must be equipped not only with mask but with protective clothing. At all permanent, or semi-permanent installations, expensive decontamination equipment must be present and it must be manned. All civilians must have masks and a safe place where they can take refuge during a gas attack.

In the early part of a war the main objectives of air

attacks are generally the enemy air forces, airdromes, arsenals, supply installations, and industrial centers. Chemicals of the mustard gas type doubtless will be used in conjunction with high explosives in attacking such objectives to cause confusion, delay repair, and to destroy morale. If the purpose of an attack is to neutralize or prevent operations from an airdrome, or to cause casualties among the personnel, no method will give quicker or more effective results than airplane chemical spray combined with high-explosive and chemical bombs.

Troop concentrations, especially during the early stages, will offer excellent targets for chemical bombing by aircraft. As troops move into concentration areas, they may be attacked by bombs and possibly by chemical spray. Regardless of the actual number of casualties, the use of persistent gases which attack the entire body will cause delay and disorganization unless complete provision, including training and equipment, is made to anticipate this form of attack.

The text on chemical warfare for the Red Army states that air chemical attack to cause casualties must be made against concentrations of troops in bivouac areas, in reserve, or when entraining or detraining at railroad stations. For such targets the use of chemical bombs combined with H.E. (high explosive) and incendiary bombs is advised. For striking columns the chemical spray is favored over attack with bombs. Under conditions of modern gas discipline losses from bombs will be chance losses and the return to the march may be quickly effected. In the case of spraying, however, the losses may be large, especially if the attack can be made in a narrow place where the column cannot spread out, and atmospheric conditions are such that the mustard gas or Lewisite spray itself can settle on the forces attacked. Striking the reserves located in

forests is especially advantageous. Here the persistent gas bomb is much more effective than the high-explosive fragmentation bomb, according to Red Army teachings.

Main bodies in the rear, bivouac areas, large troop columns, and important headquarters are better targets for air attack with chemicals than are forward troops whose actual location is of course less easily ascertained and who are in much smaller groups.

Mobile troops operating in front, advance guards, and patrols, are likely to encounter bands of mustard gas which have been placed on the ground to delay their advance. An enemy might do this by air either by bombing or spraying. Spraying would have to be repeated every day or two in order to maintain a dangerous concentration. Such use of persistent gas will be especially effective in defiles, along main routes, at river crossings, or where there are natural obstacles which must be passed.

During a pursuit the most likely form of gas attack is the airplane spray. Defiles may be bombed with H.E. and persistent gas, and bands of persistent gas placed ahead of the retreating enemy column at key points.

Although not much detailed information has been released, it is true that mustard gas was one of the most important factors in the defeat of the Abyssinians by the Italian Army in 1936. For a long time Italy denied that chemical agents had been used against their enemy but reports of observers, correspondents, and especially of members of the British Red Cross who served with the Abyssinian forces have confirmed the fact that mustard was used in airplane bombs and by spraying from airplanes on a large scale and with great success.

Major General J. F. C. Fuller who was with the Italian

Army as a special correspondent to the *London Daily Mail* during the Italo-Abyssinian War, says in *The First of the League Wars*, "It is no exaggeration to say that mustard gas sprinkled from airplanes was the decisive tactical factor in this war, because it shortened its duration by months if not by years." Regardless of whether or not chemicals were the deciding factor, they proved to be an extremely powerful weapon.

Perhaps the most serious problem the Italians had to reckon with in their advances in Abyssinia was the security of their flanks while moving through the mountains. Most of their movements were across rugged, difficult and barren ground requiring the construction of a motor road as the march proceeded. For a period in 1935 the situation looked rather unfavorable for the Italians. There was constant danger that, as the Italian columns became further separated from their bases, attacks from the flank and rear would cut them off from their supplies. The country was swarming with Abyssinian guerrillas. From the heights the natives skilled in fighting in the mountains raided and harried the columns along the lower slopes where only could motor roads be built.

General Badoglio took into account the fact that many of his troops were recruits and lacked training in mountain warfare. He finally resorted to mustard gas to protect his flanks. Instead of picketing the heights on either side of his columns, he gassed the areas bordering the flanks of his advance with mustard. The result was that when the enemy entered these mustardized zones, thousands of them were burned. The Abyssinians fought barefoot and wore few clothes so they were especially vulnerable to the action of a blister gas. After two or three experiences, Italian flanks were left alone.

General Badoglio also adopted very effective offensive gas tactics when opposed by large masses of the enemy. He used machine guns to prevent their advance against him and at the same time used airplanes to bomb and spray the rear of the enemy masses with mustard gas. Finally by low-flying attack with machine guns and fragmentation bombs he drove the enemy into the gassed area. It was not long before the Abyssinian morale collapsed.

The most interesting and spectacular example of aerial chemical attack took place in January, 1936, after the Italians had penetrated well into Abyssinia and had occupied Makale. They had moved rather rapidly up to this time, but beyond Makale their advance was slowed down. At this time they held a long line extending on the east to the Takazze River which because of heavy rains was high.

The Italians believed that the high water and steep banks of the river provided reasonable protection for their east flank. However, they did hold the fords and possible crossings with small forces. Across the river was a large force of Abyssinians under the two chieftains Ras Kassa and Ras Seyum. Suddenly, with speed and daring, the army of the Rasses crossed the Takazze, annihilated the small forces guarding the fords, and the Italians woke up to find an army on an unprotected flank. The road to their rear was open. There was no time to bring forces from the left to ward off the attack. It looked very much as if the Italian right column might suffer another Adowa.

It was at this time that the air force proved to be the Italian salvation. All planes available were sent to strike the Abyssinians who were advancing against the bases of the Italian army. The planes struck the attackers on the flank and rear but carefully refrained from using machine-gun fire or

bombs on the front of the advancing masses. They did not want to disperse them. Chemicals were used on a large scale here for the first time. Haile Selassie's forces were heavily sprayed with mustard gas.

Of course, the Abyssinians could not understand this. They had never experienced anything like it before. This rain falling upon them smelled bad, but was not especially irritating at first. They pushed on, still in mass formation, and the Italians continued to spray them. It takes hours for mustard gas to get in its effect; but that effect, when it is finally exerted, is a powerful one. Within four days one of the finest armies of Haile Selassie was in full flight.

We know what mustard gas will do to the average soldier. It is well to recall that the Abyssinians were barefoot and some of them didn't even have a shirt. No one knows the extent of the casualties. The army of Ras Kassa and Ras Seyum, however, lost its identity as a unit, and the flank and rear of the Italians was saved.

Although the use of mustard spray and bombs from airplanes in the Italo-Abyssinian war was the first time air chemical warfare had been used on a large scale in war, airplane mustard bombs had been used by the Spanish in their campaign against the Riffs in Morocco in the spring of 1925. There have also been rumors that gas was used from the air by the British against tribesmen on the Afghan border in the early 1920's and by Soviet flyers in Turkestan soon after the First World War, but it has not been possible to verify either of these reports.

Gas has its effects also, unfortunately, in civil activities. An attack on an industrial area is intended to stop or delay production of essential war materials, to cause confusion,

and, incidentally, to reduce morale. Some delay is certain to be caused by every attack. The mere fact that hostile airplanes are overhead will affect output adversely. With high explosive bombs a direct hit or near-hit is necessary to cause destruction. When the debris is cleared away, construction can begin. Add chemical bombs to the high explosive, however, and great delays are caused in clearing the debris. The persistent chemical must be removed before reconstruction can start. The gas bombs do not have to hit the target to be effective. Until the gas has dissipated, all work in the neighborhood must be done wearing protective clothes and a gas mask. The threat of gas demands that everyone be equipped with a gas mask and protective clothing and skilled in its use. Civil defense agencies must recognize the added burden which this puts upon them.

Not much has been said about the use of non-persistent gas from the air but it is my belief that phosgene and other quick-acting non-persistent gases, if used in large bombs, may prove overwhelming in their effect. Tremendous concentrations may be obtained in the vicinity of the burst of a 500- or 1000-pound bomb. When there is a requirement to obtain casualties instead of destroying material, the large non-persistent bomb is likely to be more effective than high explosive especially where personnel are well protected from explosive.

X

THE EMPLOYMENT OF GAS IN BATTLE

WE cannot properly be prepared against a weapon unless we know all the ways in which our opponent might use that weapon. It is vital that the soldier understand the tactical use of chemical agents. It is also vital that the noncombatant, against whom they may also be used, have a knowledge of these same facts.

In a previous chapter the gases are classified as either casualty agents or harassing agents. Casualty agents are those causing death or casualty sufficient to send a man to the hospital. They are the choking gases like phosgene, or the blister gases like mustard. Harassing agents, which include tear gases and sneeze gases, cause only temporary disability. Unless a man puts on his gas mask, however, the harassing agents will make him ineffective as a fighter or worker. The war gases have also been divided into persistent and non-persistent agents. We have, therefore, non-persistent casualty or harassing agents and persistent casualty or harassing agents.

This matter of persistency is very important for it has a great deal to do with the way in which a gas is used. It is important also to remember that the method of employment may determine the degree of persistency. For example, mustard gas when sprayed from an airplane is not very persistent—it lasts only a few hours—but if fired in artillery

shells or dropped from an airplane in bombs, it is very persistent, lasting frequently as long as a week—remaining effective all this time.

This fact affects the use in battle. If it is necessary to contaminate ground so that unprotected men cannot remain on that ground for a period of time, say three or four days, shells or bombs should generally be used in preference to spray. Spray will cover a greater area, but since the sprayed agent will last only a short time, probably less than a day, spraying would have to be repeated in order to keep the ground contaminated. On the other hand, if there are personnel on the target and it is important to cause as many casualties as possible, spray will generally be used in preference to bombs, for this method gives greater coverage and more likelihood of each man on the target being hit, or contaminated.

Military writers have formulated a great many principles which are supposed to govern the art of war. Many of these principles when shorn of their fancy language are truisms which any intelligent man knows without being told. Surrounded with high-sounding words and military terms, however, they are calculated to impress the layman.

Lest the writer on chemical warfare be outdone by the expert on the older forms of warfare, let's see how some of these principles of war apply to military chemistry. The applications may not be immediately apparent so explanation is in order.

The principle of surprise, probably most important of all the war principles, stands out as the first to be mentioned. Many have said that it is the principle upon which the bets are finally paid off. If we can find a new gas and take full

advantage of surprise and use this gas on a grand scale, it may be possible to decide the issue for which we are fighting then and there. Failure to employ this rule caused Germany to lose two big chances in the World War—the opportunities presented by the first gas attack and the first use of mustard gas. When the nitrogen mustards or any new agents are used, they will be used in great quantity and with maximum surprise.

Concerning the methods of firing gases, there are two points in connection with surprise which are important. In the first place, surprise is an absolute requirement if non-persistent gases, such as phosgene, are to be used successfully. A modern enemy is sure to have a good gas mask and be well trained in its use. If our agent is to be effective, it must get in its effect before he has adjusted his mask. Consequently, a non-persistent agent must be fired in a high concentration by a sudden burst with consequent surprise effect.

Another point in connection with surprise is that persistent agents of the mustard type should be fired so that their use will not give away the tactical plan. For example, if you use mustard gas on a flank, your enemy will have reason to believe that you do not intend to move around that flank. Mustard is slow in its action, so it should be fired at such a time as will allow its effect to develop and yet late enough in an attack so that the defender can not easily change his defense and move to another position.

Since the effect of chemicals is continuous in time and space, it is not confined to the impact area as is the case with high explosive. When using chemicals, the plan of fire must be coordinated so as not to hamper nearby or adjoining units. If this principle of cooperation is ignored, a near-by friendly unit may be delayed in an attack by an un-coordinated smoke

screen blowing across its front, or may suffer casualties from gas intended for the enemy.

It will be apparent that concentration is important. Dispersion of an agent over many targets reduces and may nullify its effect. Where only a small amount of chemical ammunition is available it should all be massed upon a few targets. Gas should never be used on a small scale for casualty effect. It is correct to use a few tear-gas shells to harass an enemy (to keep him masked), but if an agent is intended to produce casualties or to deny occupation of ground plenty of it must be used.

Plans for a chemical operation should be simple. It is undesirable to use many different kinds of agents. A complicated chemical plan makes it difficult for the organization which is supplying the ammunition, as well as for the unit firing.

A chemical agent should not be fired on a target that will be occupied by friendly troops during its effective period. This does not mean that persistent agents can not be used before an attack. It does mean that you should use them on ground outside of your path of advance or which you do not intend to occupy later while the gas is effective. A commander trained in the use of chemicals will select an agent of such persistency that it will have dissipated before his own troops arrive on the target.

Gas differs from all other weapons in that a target does not have to be occupied at the time of fire in the case of persistent agents. Thus it is possible by placing a persistent blister gas upon it to deny ground to an enemy or make it difficult for him to occupy it. At the very least it is practicable to delay an opponent by placing a persistent gas barrier across his path. An enemy finding a gassed area in

front of him must either go around it, which takes time, or go through it. He can not go through it without casualties unless he is protected by a gas mask and, in the case of blister gases, by protective clothing. The wearing of the protective equipment alone will cause delay.

In the case of non-persistent agents, the target must be occupied at the time of fire. Non-persistents can not be used for contaminating ground. It is inadvisable to fire non-persistents unless there are enough men on the target to make it a profitable one.

Again, in the case of the phosgene type agents, they must be fired in sudden heavy concentrations. If you cannot get your concentration of non-persistent agent on the target within one or two minutes, you had better save your ammunition.

In every situation there are certain targets which must be covered. Chemical munitions form only part of the munitions which will be available. They will be used only when they can accomplish a mission better than bullets or explosives, or when they are needed to augment other munitions. The selection, therefore, depends upon a decision as to which of the targets that must be covered will be chemical targets or high explosive targets or both.

In wooded areas wind velocity is reduced and rising air currents are eliminated. If gas is fired into woods, it is likely to stay there and exert its maximum effect. Shells or bombs hitting tree tops and branches explode well above the ground. In the case of blister gases, an air burst, and, consequently, a valuable spray effect is obtained in this way. Woods, on the other hand, afford some protection from high explosives. Therefore, a wooded area might be a much more suitable

target for mustard-gas shell, for example, than for high explosive.

When the target is located in an open space, where there is not much undergrowth, gas will be dissipated more rapidly. Unless a man is in the immediate area of the burst or lies on the ground, there is not much chance of his becoming seriously contaminated with the mustard type agent providing he moves off quickly and adjusts his protective equipment. In the open, however, he gets no protection from high explosive unless he digs a hole; there is no convenient tree for him to get behind. In this case high explosive may be the most effective means of getting immediate casualties, although if there are sufficient men on the target, it will be a profitable one for airplane chemical spray. In connection with high-explosive fires, it is well to remember that by mixing even a little tear gas with (HE) shell, the enemy may be required to put on a gas mask.

A heavy gas seeks lower levels; it hangs in low places or pockets. It is generally easy to reach with gas those targets that are protected from high explosive. We may be influenced in selecting gas in preference to high explosive if the enemy is in a ravine or a low spot. The combination of woods and low ground provides the ideal target for chemicals, so far as terrain is concerned.

The size of a target and the number of personnel involved are considerations. If there are a given number of shells of each type to fire, a decision must be made whether the mission can be accomplished better with high explosive or with gas; whether if casualties are sought it is likely to get more with one than with the other.

Moving targets in forward areas are not good gas targets. It will probably be impossible to get the high concentration

DECONTAMINATING A MUSTARD GAS SHELL CRATER
Men are wearing impermeable protective clothing.

U. S. Army Signal Corp.

DECONTAMINATION WITH BLEACH AND SAND
Men are wearing permeable one piece protective clothing.

required for phosgene, unless within chemical-mortar range. It is not likely that more than a battery of artillery would normally be available to fire upon a moving target in a forward area. Further, if firing a mustard type agent against a moving target, troops rarely would be exposed to the fire in the gassed area long enough for the effect to be produced. In such a case a commander may consider the use of tear gas (CNS) to slow up movement, cause confusion, and thus hold the troops under high explosive fire for a longer period of time.

Moving targets in rear areas, especially those beyond artillery range, are good targets for airplane spray if they are sufficiently large and important. Troops on a road can be hit by spray and are good targets, unless the road net is so extensive that it is impossible to forecast reasonably well where they are likely to be at a definite time. Attack aviation can not search for a unit ordinarily. The target must be definitely located.

Gas generally is most effective on targets where high explosive is least effective. From the technical standpoint, the decision as to whether to use gas or high explosive should not be difficult.

The decision from a tactical standpoint depends upon the plan of battle, the agents available, and existing weather conditions. Let us assume that we have suitable targets presented. What agents shall we use? In any given situation we shall have only a few agents available. All the arms using chemicals will probably not have all type of agents available as munitions.

The amounts and kinds that each arm will have will be governed by several factors. The plan of campaign, whether it is offensive or defensive, whether it is stable or open

warfare, will be a determining factor. The season of the year and the geographic location of the theater of operations will influence the type of chemical munitions supplied. From those available, we must select those most suited.

We must observe the principle of persistency. Obviously, we should not blindly use a mustard type on a center of resistance just before our troops occupied it, even though that center of resistance were heavily wooded low ground. On the other hand, if we could reach it with our weapons, phosgene might be used.

As examples of selection, the following may be cited:

Phosgene fired for casualty effect upon occupied targets, such as platoon, company, or battalion areas that will not be occupied by friendly troops for thirty minutes. The phosgene must be delivered in a sudden burst.

Mustard might be selected for casualty fires upon targets that will not be occupied by friendly troops for several days, or for fire upon strong points which can be avoided in an advance. It may be used to neutralize airdromes or deny roads or areas through threat of casualties. It may be used for interdiction or for counter-battery.

Tear gas (CNS) might be selected for harassing fire up to two or three hours before the target will be occupied by friendly troops. It is especially useful against working parties where the desire is to delay work and movement. It is fired to force masking. It is best fired with HE shell.

Certain of the weapons are better than others for a given agent. For example, phosgene fired by a Livens projector gives a simultaneous burst and a heavy cloud is formed in a few seconds, while the 155-mm. howitzer requires the full two minutes because of the rate of fire and limited number of cannon. The characteristics of the weapons, therefore,

have an influence upon selection. There is also the question of availability. Chemical troops are in the combat team for the express purpose of firing chemicals, while artillery and air corps are in the team to fill certain needs which are considered from a tactical standpoint and not from the question of firing high explosive or chemicals.

If we assume the availability, range, mobility, time to emplace, and suitability for firing the agent are all satisfactory, then the following examples may be given to indicate the proper selection of the weapons:

The 4.2-inch chemical mortar is first choice for firing smoke and harassing agents. It is very suitable for non-persistent casualty fire upon small targets, and for fire with persistent casualty agent.

The Livens, or its successor, is first choice for firing non-persistent agents; for air weapons, the 1000-pound bomb.

The cylinder is a weapon of opportunity—for special situations—using non-persistent agents.

The land mine is first choice for gas barriers and for contaminating demolitions using persistent casualty agents (mustard type).

The 75-mm. gun and 105-mm. howitzer are first choice for persistent blister gas and are excellent for persistent harassing agents. They are not very satisfactory weapons for smoke.

The 155-mm. howitzer is first choice of artillery weapons for smoke and although not satisfactory it is the only artillery piece considered for firing nonpersistent casualty agents, such as phosgene. It is suitable for persistent casualty and harassing agent.

Airplane spray is the most effective method of dispersing persistent agents against personnel. Targets are normally

attack aviation targets, such as troop columns and bivouac areas and airdromes, and should be large and definitely located.

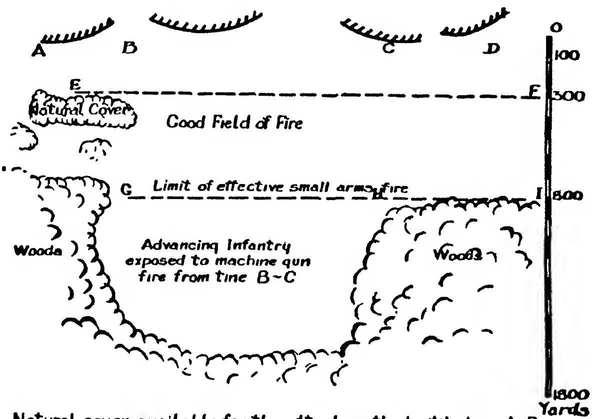
Airplane bombs are first choice for dispersing mustard type agents where persistency is desired for contamination of ground.

Some kind of chemical agent will be found useful in all tactical situations. Nevertheless, chemicals cannot be used indiscriminately, and unless the use is intelligent, they may do more harm than good.

The principle of persistency dictates that no wide general use may be made of highly persistent chemicals in the offensive. It is apparent that careful thought must be given to the possibility that persistent agents will handicap friendly troops in their attack. They can be used, but they must be used with great care lest they interfere with the plan and handicap the user as well as the enemy. Moderately persistent and non-persistent agents and smoke can be widely used in the offensive. Consequently, in offensive operations we may expect a limited use of the persistent agents on targets that can be avoided in the maneuver; general use of moderately persistent agents up to a few hours before the attack; general use of non-persistent agents up to thirty minutes before the attack. Smoke at any time needed.

Smoke is especially valuable on the offensive. Properly used, it is impossible to estimate its great advantage. Wrongly used, it may do more harm than good. Smoke fire should be controlled fire. It requires observation and regulation. Its use must be coordinated with adjoining units, lest it blow over advancing friendly troops and cover them at the wrong time and cause confusion. Smoke is most effective when

placed upon or close to the enemy observation, and, where possible, it should be so placed. It is used to deny information, to reduce fire effect and to hamper movement and operations. It has been called a two-edged sword. It presents its dangerous side, however, only to the unintelligent user. Its benefits to the wise commander who understands it are in-



Natural cover available for the attack on the hostile line A-B. No smoke needed.

No cover available for the attack on the line B-D. Smoke is needed after crossing line G-I.

The area in rear of the line G-H is exposed to machine gun fire from the line B-C. If ammunition is available the line B-C should be screened during the advance across this area and the line B-D screened during the advance from the line G-I to the assault position. Fire must cease when the advance is in the vicinity of the line E-F

SMOKE TO COVER INFANTRY ATTACK

calculably great. It denies the enemy the advantage of observation, but at the same time it may keep friendly forces from seeing him. It places the enemy on the alert. This fact may be used to call the enemy's attention to the wrong place and cause him to expend ammunition needlessly. Smoke generally draws fire; and this may be used to draw the enemy's

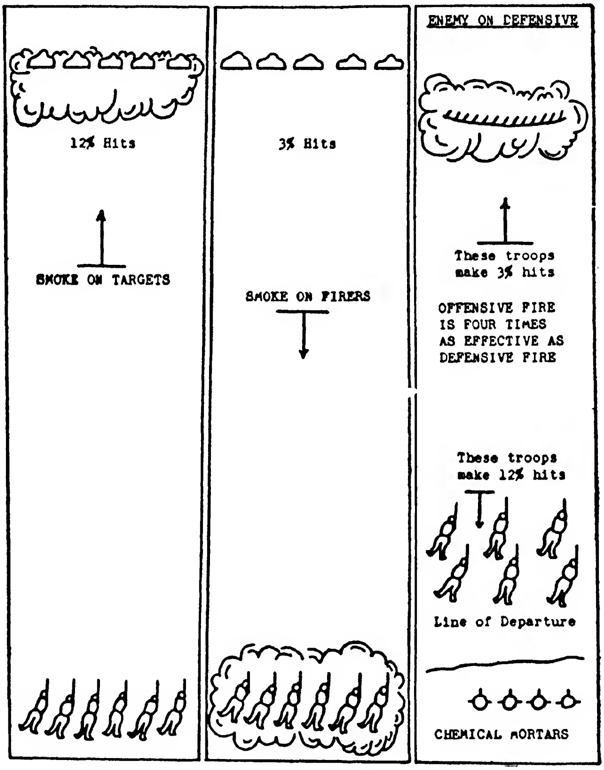
fire toward unimportant areas. It should be remembered that smoke drifts with the wind and must be properly controlled so as not to hamper other units.

An enemy depends upon observation for most of his information of our activities. Proper use of smoke will deny this observation, certainly so far as ground observation is concerned. A smoke screen may make it possible to move reserves, to bring up weapons, shift positions, and assist in obtaining surprise. Observed fire is the most effective fire. If it is possible to place smoke on an enemy, he can be denied the advantage of aimed or observed fire and thus his fire effect will be reduced.

For many years a test was carried out upon students at the Army's Chemical Warfare School to show the effect of smoke on the accuracy of rifle fire. Each class that came to the school during its course was taken to the target range where the student was required to fire five or ten rounds at silhouette targets under three different sets of conditions. Among the men who fired were Army, Navy, and Marine officers, Regulars and Reserves, and enlisted men of all grades. Some were experienced rifle shots; others had never fired a gun.

For the first test ten shots were issued to the firers who took prone positions on the butts and at a signal started firing at the targets 300 yards away. The average number of hits over a period of years for this test has turned out to be 55%. For the second test ten more cartridges were issued and at the time the command to fire was given, a smoke screen covered the targets. With the smoke on the targets, the same men got an average of 12% hits. For the third test more shots were given the man and this time at the command to

fire, smoke was placed on the firers and they were completely surrounded with it. The average number of hits in this last case was 3%. From these repeated tests of firing



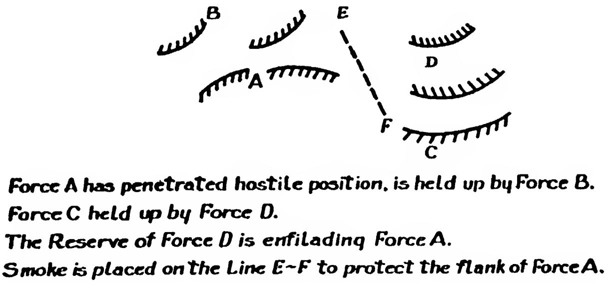
THEORY OF EFFECT OF SMOKE ON FIRE POWER

through smoke conducted for more than ten years it has been learned that smoke on the defender's position will give an advantage to the attacker of over four to one (4:1) in relative fire efficiency over that obtained without smoke. The attacker who has smoke on the enemy cannot see the

enemy but he knows his approximate position. The defending enemy, however, is completely covered with smoke and has lost his bearings—he is completely disoriented.

The armies of the world understand the great value of smoke and are well acquainted with its effect on fire power. Much use is being made of the smoke screen but all of its advantages have not yet been exploited.

Smoke can be used to protect an advancing unit from fire from a flank, to assist in effecting reorganization, to mask a

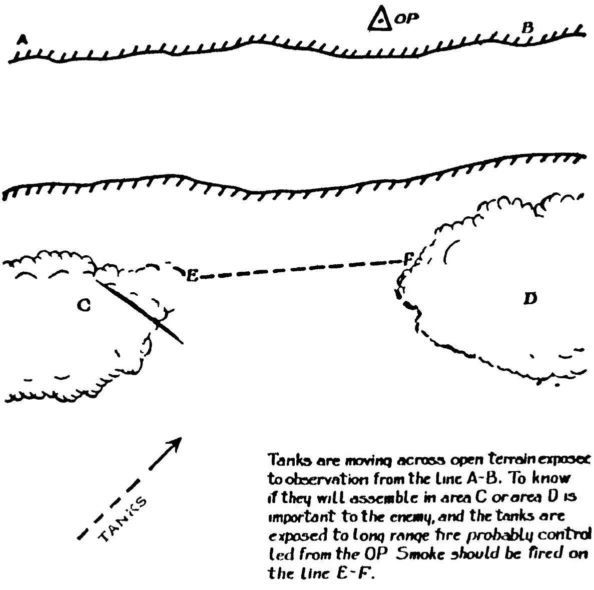


SMOKE TO PROTECT THE FLANK OF AN INFANTRY UNIT

gas attack, and generally, in any situation where concealment is required. At times it may be useful to retard or hamper the movement of hostile tanks. Not only does smoke cause the tank to reduce speed but when the tank emerges from the screen it presents a perfect target for the anti-tank gunner as it is outlined against the white background.

A description of the use of smoke by the Germans in the penetration of the Maginot Line appeared in an article by a Colonel Kanzler in the *Deutsche Allgemeine Zeitung* of Berlin dated May 22, 1941. The article told of a smoke unit which had been assigned a mission at the strongest point of the Maginot Line between St. Avold and Saaralben.

The permanent steel fortifications and field fortifications of the French were located on high ground behind wide basins of dammed-up water. Wide rows of barbed wire in the swamp land adjacent to the water basins, and along the edge of the basins themselves, gave the impression that an approach to the enemy positions or a crossing of the water



SMOKE TO COVER THE MOVEMENT OF TANKS

was impossible. The French, who felt themselves secure behind concrete and steel, were able to direct the fire of their machine guns and rapid-fire cannon against every knoll and every depression of the ground before them.

The German division artillery commander ordered the smoke battalion to screen the line of hills and the slopes on the far side of the bottoms. The southeastern exit of the

village of Remering, which was strongly fortified by the French, was also to be enveloped in smoke so as to prevent observation. According to the plan of attack the fortified heights of the French were to be "blinded" in order to make it possible for German infantry to detour them on both sides and then destroy them from the rear. This made the employment of additional strong infantry and artillery units unnecessary. In particular smoke was to make it impossible for the French to direct accurate fire at the flanks of the attacking infantry. It was to be used to help save blood.

The smoke battalion maintained a screen over an area 2200 yards long and 450 yards deep by firing one round every fifteen seconds from each weapon. This battalion was equipped, at least in part, with five-inch mortars. It had forty tons of ammunition available for use in its attack against the Maginot Line. Let Colonel Kanzler give the results in his own words:

Our employment was a convincing success. We were very much pleased to hear the words of praise coming from the assault troops and the heavy weapons engaged in this battle. . . .

The smoke screen on the morning of the second day of the battle made it possible for the infantry and pioneer assault troops to approach the artificial lake, and for two assault groups to cross the lake on inflated rubber rafts.

A platoon leader of a 10.5-cm. assault battery reported that under cover of the smoke he proceeded with his armored weapon to within a few meters of the enemy bunker at the entrance to the village of Remering and put the bunker out of action by firing into the embrasures.

This brilliant success was not only due to favorable local conditions, but also to years of experiment with this weapon and the thorough training of officers and men which commenced winter before last.

In defensive action a much wider use of mustard gas and the persistent chemical agents is practicable. In the passive defense there is no intention to advance. Consequently, considerations of persistency do not prevent the general use of any agent. Chemicals in defense may be compared to an obstacle such as a stream. The wider and deeper the stream, the greater an obstacle it is. Similarly with the chemical, the wider the area contaminated with blister gas and the stronger the concentration, the more of an obstacle it presents to the enemy. The longer it remains an obstacle, the stronger is the defense. A wide use of persistent gas on the front or flanks of a defensive position may break up an attack, since no enemy can move across without heavy casualties or without the use of hampering protective equipment.

In firing upon a small target, such as a crossroad, about all that is practicable with gas is to force masking. For fire on a small area to prevent its use by an enemy, HE will perhaps prove more useful than gas. If a few tear-gas shells are fired with the HE, however, it will retard the movement, cause masking, and hold personnel under the HE fire longer, since movement is slower. Since the attacker has freedom of movement, it will generally be difficult to catch him with the volume of fire that will give the required concentration of non-persistent gas.

Gas finds a very wide use in the special forms of defense and little need be said upon this score, since the application is generally obvious. In the defense of a defile, persistent gas might be placed well in front on the avenues of approach in order to cause delay. Should the defender be pushed back into the defile, it would be profitable to place a barrier of gas at the entrance and one or more similar barriers within the defile itself. In the defense of a river line, persistent gas

can be fired upon the attacker's side of the river to deny ground and perhaps limit the number of favorable crossing points. Critical areas which can not be observed from the defender's side of the river are especially suitable for such use of gas. In beach defense there are many ways gas may be used to prevent a landing or prevent an enemy from securing a beachhead. In a withdrawal from action and a delaying action, chemicals are extremely useful. Persistent gas and smoke are the types most valuable in these operations. Demolitions are widely used in retrograde movements. If they are contaminated with mustard, the delay caused will be greatly increased.

Smoke has its greatest value for use by forces on the offensive. It also is useful on the defensive, however. If the attacker is using smoke and the defense has already lost the effect of aimed fire, it may be well to place him in smoke to equalize things. Smoke may be used within friendly lines to cover changes in dispositions; to cover a movement of artillery; to permit troops, who are exposed to enemy observation and fire, to withdraw to another position. A smoke screen may be particularly valuable to cover a cavalry withdrawal. In this case it will be needed only for a few minutes —just long enough to permit troopers to mount and move off.

A successful use of chemicals in the attack or in the defense requires a knowledge of the principles and of the behavior of chemical agents. It isn't enough just to shoot them over at the enemy and let it go at that.

XI

GAS ON A HOSTILE SHORE

AFTER two years of preparation, the Greek fleet and army assembled at Aulis in Boetia to avenge the seduction of Helen, wife of Menelaus, by Paris, son of Priam, king of Troy.

"The wind thereupon proving fair, the fleet made sail and brought the forces to the coast of Troy. The Trojans opposed the landing valiantly. At the first onset many were slain and one of the noblest of the Greeks, Protesilaus, fell by the hand of Hector."

Several thousand years later another fleet stood off Gallipoli within cannon shot of Troy. The Turks opposed the landing valiantly. At the first and later onsets many were slain and thousands of the English fell by the hand of the Moslem.

The passage of years has not lessened the problem which confronted Greek and Englishman. The landing of troops on a hostile shore is still one of the most difficult operations of war. If the defender adds chemical weapons to his inherent defensive advantage, the task of the attacking force becomes still more difficult.

"A plan of campaign," Napoleon said, "ought to have foreseen what the enemy is able to do, and should contain the means of checkmating him. . . . It should be carried on

with means proportional to the obstacles which can be foreseen."

One of the important obstacles that must be foreseen is the *chemical* obstacle. Every plan for a landing operation must take into account the probability of encountering chemical agents and provide a means of overcoming them, so long as there is a reasonable chance that the enemy may use gas.

As a defensive instrument, the chemical agent is extremely valuable and flexible. It serves many purposes and not the least is to provide an effective defense over a period of several days without the necessity of holding a large number of troops on the ground to be defended.

It is necessary first to foresee the obstacles; to outline the ways in which a defender might make use of chemical agents. Having done this, it is time to find the means to overcome his chemical defense.

The practicable landing places will generally be few owing to the conformation of the shore line, the depth of the water, the presence of surf, or the prevailing winds. The defender will often be able to make a fairly accurate estimate of where a landing is likely to be made and to plan his defense ahead of time. Certain factors that cause selection of a landing beach make the place favorable for chemical defense. For example, the necessity for relatively quiet water makes a landing likely on the shore protected from the wind. In the lee of the land the wind, in general, is favorable for the release of cylinders of gas from headlands or even from beaches.

While troops are aboard the transports and until they are close to land, they run no great risk from chemicals. There can be little chemical fire against the ships. Certainly the use of non-persistent gases against ships need not be considered,

and aside from the presence of tear gas, in combination with shell or shrapnel, there will be no probability of chemicals from mobile artillery. Armor-piercing shell from shore batteries may carry a proportion of irritant agents mixed with high explosive. Bombardment aviation may use phosphorus or mustard-gas bombs, but it is doubtful if a commander would substitute either for high explosive. He seeks destruction and there is no substitute for HE as a destructive agent. Nevertheless, some bombs of mustard gas may be mixed with explosive to increase confusion and to force the wearing of masks.

An attack by bombardment aviation seems unlikely, since the landing would not be attempted without local air superiority or at least definite air advantage. Aviation would have failed in its mission if defending planes should be able to deliver a bombing attack against the transports or their protecting naval vessels. Nevertheless, large ships which have stopped in the open ocean are excellent targets and their vulnerability to attack by aircraft should not be lost sight of since the enemy might well have held back some of its air strength for the critical moment when troops are disembarking in small boats for the actual landing.

The first important chemical attack on the landing force will perhaps occur during the time the troops are disembarking into landing boats and the tows are being formed. During this period the attacker is most vulnerable. A few planes carrying mustard spray can cover a wide area and cause tremendous damage and confusion. Conditions will favor the use of the chemical spray, and the results to be obtained are so important that the defense may hold out a number of attack planes well concealed and loaded with blister gas to use as a last resort for this critical moment.

The wind permitting, the enemy might easily release a heavy cloud of irritant gas from headlands in such a way that it would cover the area the incoming small boats must pass. This is not at all improbable since the very condition of weather favoring the landing may most likely favor the launching of the chemical cloud. When such use of gas is practicable, it will place the troops coming in at a great disadvantage. Wearing the gas mask will be an absolute requirement; and landing in a mask is, to say the least, a difficult job.

As soon as the first boats are within range of enemy machine guns, the run-in may be covered by smoke laid by friendly airplanes, either as a screen by spraying or by dropping floating smoke pots. Phosphorus bombs may be dropped along the beach. Mortars on landing barges provide an especially satisfactory means of laying a blinding screen either on the beach or by smoke shells bursting on the surface of the water. This presupposes, of course, that the element of surprise has been lost as at Tarawa and that it has become necessary to land against resistance. The smoke stops the enemy from delivering aimed fire. Hence where resistance is expected, smoke is essential and the wise commander will use plenty of it in gaining a toe hold on the beach and in securing and holding it. He will improvise as well as use every standard smoke device.

As the attack reaches the beach, the defense again has an excellent opportunity to employ mustard spray. Since aviation can swiftly lay a band of chemical a mile long and several hundred yards wide and since there is a large area to be covered, spray should be a powerful weapon.

It is after a beachhead has been gained, however, that the chemical difficulties of the attacking force really begin. Up to this point the use of chemicals has been largely a question

of opportunity; but now they offer a sure and definite advantage to the defender.

The first mission of the landing troops is to secure the beachhead and then push ahead to their final objective. Delay is dangerous. They must organize and go forward at once. The forward impulse must not be lost. It is accepted tactical doctrine that in passing an obstacle, whether bridge, defile, or beach, there must be a fanning out in order to gain shoulder room. If hemmed in by natural or created obstacles on the flanks, and the ground to the front is held by determined men, the results will be meager indeed for the landing forces.

The lack of shoulder room because of natural obstacles was one of the reasons for the failure of the British at Gallipoli. So far as the actual landings were concerned, they were accomplished successfully. The British secured a foothold, but that was all. There they were, hemmed in by natural obstacles on the flanks and difficult ground held by a determined enemy in front. The holding power of modern small-arms fire was too great to admit of any successful argument under such conditions.

Persistent chemicals will be highly effective in increasing the difficulties of natural obstacles. Where these obstacles do not exist, a liberal sprinkling of mustard will often prove a first-class substitute. Should the attacker have ample room to deploy, wide bands of mustard, perpendicular to the shore line, will delay the lateral movement. The chemical may be fired in wide bands by means of land mines, or by artillery, airplanes, or chemical mortars.

Persistent blister gas will be effective for hemming in the landing party and preventing the lateral movement that is so necessary to the attack in its exploitation of the beach-

head. It is true that passage is not physically barred by any chemical agent; but maneuver over the contaminated ground is hazardous, cannot be accomplished without wearing the gas mask, and is certain to result in large numbers of casualties and reduction in morale and efficiency.

By making full use of chemical obstacles the defense can hold ground with a smaller number of men than otherwise would be possible. Contaminated areas will generally be swept by fire from machine guns and artillery, thus slowing the attack and keeping it close to the ground surface where the contamination is greatest.

Where winds are dependable, as they are in many cases, and narrow corridors exist along which landing troops must pass, gas clouds of non-persistent chemicals released from cylinders or projectors may be encountered. In fact, a landing force may meet with chemical attack in all of its many forms if the defense has been able to anticipate the landing.

The conditions of zone defense exist and the enemy generally will have had an opportunity to make all preparations. Chemical attack that would not be possible under a mobile situation due to time and supply factors is possible in this case.

Now, as to overcoming or neutralizing the chemical defense: A landing on a hostile shore really starts on friendly soil, weeks or months before embarkation. Perfect gas training and the best possible anti-gas equipment are essentials for a landing force.

The chemical defense organization should be more complete than that ordinarily required for land operations. Each company will require its regular quota of two gas non-commissioned officers. Each battalion, in addition to its gas officer and non-commissioned officer, should have a squad carefully

trained in chemical reconnaissance methods and equipped to conduct degassing operations on a small scale. Each regiment should have a similar squad under the direction of the regimental gas officer. This personnel must be intelligent—selection by hit-or-miss methods will not do. Such a squad is normal in Italian regiments.

The methods of protection against gas are discussed in detail in chapters that follow. Reference to these chapters should clear up any questions the reader may have about anti-gas equipment and the various protective measures which are mentioned below.

Before embarkation the commander should make certain that all anti-gas equipment is available, serviceable, and ready to go over with each landing wave. Every man must know how to use his protective equipment, and understand how to behave when exposed to chemicals. First-aid training for gas casualties should be included. There must be repeated exercises aboard ship to accustom the men to wearing the mask for long periods. Working while masked develops the ability to fight while masked.

In the landing itself, protection is very much of an individual problem. There is little chance for measures for group protection. As soon as the first sub-wave has reached the beach, its mission is to push forward and secure the landing for the succeeding sub-waves. As soon as it is possible to organize, the first wave must secure the beachhead and push forward to the principal objective immediately. Any delay in the forward movement will be costly to the attack. Speed is the essence of the operation. It must be assumed that gas will be used by the defense to cause all possible delay and prevent the attack from getting shoulder room.

In the solution to the problem of protection against gas,

therefore, all steps possible will have to be taken to overcome any slowing of the attack through the presence of gas laid down by the defenders.

In order to assure the best possible handling of the situation, regimental gas officers with their assistants should accompany the shore party commanders, or at any rate land with an early sub-wave. Their first duty will be to make an immediate reconnaissance. They will determine whether or not the defenders are using gas, and particularly whether or not the defense has laid down barriers of mustard gas.

Chemical defense squads under battalion gas officers should accompany their units in each sub-wave as an integral part of the combat team. These chemical defense squads, composed of specially selected men carefully trained in gas defense should have trained noses and be able to detect and distinguish the various gases. All should be equipped with protective clothing for making a way through gassed areas. They should carry cutting tools, small intrenching shovel, and materials with which to clear lanes through such heavily contaminated brush and undergrowth as must be traversed. The danger of bodily contact with vesicant agents on grass, undergrowth, overhanging branches, cannot be eliminated entirely but it can be reduced by skilled personnel.

It is an open question whether or not it will be possible for the members of the chemical defense squads to carry some small amount of degassing material. If found practicable, they should carry chloride of lime, perhaps twenty-five pounds contained in knapsacks strapped to their backs. Between them it may be found that each squad is able to carry a couple of hundred pounds for small degassing operations. Obviously degassing will be impossible on any except the smallest scale; but it is essential that some be done.

For instance, the degassing of the small space to be occupied by the portable radio apparatus is most important. Communication between the landing party and the commander of the operation must be maintained. Occasions will arise where some degassing is absolutely required. Degassing material will be extremely useful at the entrances and exits of contaminated trails. Foot burns may be reduced by requiring the men to scuff their feet in the chloride of lime at these places.

As soon as the anti-gas squads have landed, they will act under the orders of the gas officers in making a chemical reconnaissance. If there are gassed areas, it will be their duty to find them; to locate the extent of the obstacles; to find a way around them if possible, and if not to locate or make the best way through them. Some of the personnel will be used as guides to indicate to the advancing troops the way they should go if gas obstacles are located.

Active counter measures will, of course, be taken against enemy gas as soon as possible. The artillery, when it becomes available, will direct counter-battery fire against enemy guns which may be laying down persistent agents. Here again degassing may be necessary at the battery position.

Medical personnel will have special duties in case gas is encountered. It should be possible to set up field stations near the beach where men contaminated with mustard gas may be bathed. There will be plenty of salt water on hand, and a bath with salt water and issue soap will reduce casualties materially.

When the beachhead is secured, the anti-gas personnel will take measures for degassing those areas that must be occupied, or along which troops and supplies must pass. Extra precautions will have to be taken to protect food and water that is

being carried from the shore inland. Dangerous areas will be posted with signs, and in some cases sentries placed to prevent passage through them.

Since wind and weather conditions may favor continued use of chemicals by the enemy, all precautions against non-persistent clouds must be taken. Constant inspection of the protective equipment is necessary.

A definite plan of protection is an absolute essential; without such a plan a landing force is likely to find it impossible to accomplish its mission against a first-class foe.

The other side of the problem, that of protecting the beach defense against enemy gas, is equally important and demands as careful consideration as does the protection of the landing party. Again it is necessary to foresee the obstacles before attempting to set up a system of defense.

It is interesting to note that in a landing operation there is a point when the advantage in the use of chemicals passes from the attacker to the defender. Up to the time the attack has reached the beach; that is, when the landing party leaves the boats, the chemical advantage, such as it is, has been with the attack. As soon as the attack has reached the beach, the chemical advantage definitely changes hands and rests with the defense.

There are several rather remote possibilities of chemical attack that the beach defense might be prepared to resist. It has been suggested that swift-moving destroyers may run in to within a few thousand yards of a beach and discharge clouds of irritant gas under cover of the darkness. This, of course, presupposes that weather conditions favor the drift of the cloud. However, if practicable, it should prove a very effective form of attack; only a very alert gas sentry and

alarm system and a high degree of training in mask adjustment could cope with it. In a like manner, surface or underwater craft might discharge non-persistent gases such as phosgene in high concentration.

Frequent attacks by either of these methods, if they can be accomplished, would do much to wear down the defenders and reduce their effectiveness. Irritant gases in combination with high explosive may be fired from naval guns. Unless men can function well in the gas mask, the efficiency of the defense will be injured.

There is a possibility that persistent agents may be used in spray or bombs from naval aircraft. Such agents would not be used directly on beaches where landing is contemplated; but may be used on points outside the intended landing area, or against reserves to prevent their reaching critical points. Such use would demand that the defense have protective clothing, protected shelters, degassing materials, and also be prepared to move to alternate positions chosen in advance.

Important installations in the rear should be protected by large area screens produced by smoke generator units. Smoke screens were used very successfully in North Africa where one German bomber pilot was heard complaining by radio in midair to another that he couldn't find his target "because of that damned smoke." In addition to the new Smoke Generator Mechanical M-1, a new, much smaller, and more mobile generator is being produced which will extend the uses of the smoke companies.

Area smoke screening has proved to be a definite success, and weight for weight, smoke is worth inclusion in any seaborne operation. Experience in landing operations, as well as others, have demonstrated that existing chemical warfare doctrine is correct and undoubtedly will be followed in future operations.

The defender must expect a landing to be made under cover of smoke either from planes, destroyers, or from naval gun fire or from smoke mortars and guns on landing craft. Aiming points close to guns should be provided in order to permit some accuracy of fire while distant reference points are obscured by smoke. The foregoing are some of the possibilities with which the beach defender may be confronted, so far as chemicals are concerned. A protective scheme must take account of such methods as are not unreasonable, and an enemy must be credited with an ability to accomplish that which is reasonably possible.

In the protective scheme against this attack all means of individual protection are necessary.

A further and very important requirement in training is wearing the gas mask for long periods so that efficiency will not be too greatly reduced when men are compelled to wear it in action. Training is necessary in the operation of the beach guns while wearing the mask, and training in firing while in smoke. The ability to make repairs and to correct stoppages in the dark, or in heavy smoke, is important. Beach groups frequently are isolated and men are very much on their own. A high state of gas discipline and training is necessary under such conditions. Men must be trained to meet gas situations alone and have confidence in their ability to protect themselves without the help or advice of an officer or a non-commissioned officer. A knowledge of first aid, if gassed, is an essential.

Since the defense of a beach is conducted by very small groups, there is little opportunity for collective protection for the advanced elements. Gas-proofing of the beach guns may not be practicable. There should be, however, gas-proof

shelters in the vicinity of the guns where a part of the personnel may rest and be secure against enemy gas. Gas-proofing of command posts and communication centers is necessary. Communications must function effectively if the defense is to be successful, and any delay caused by gas may be costly.

Reserve positions will require gas-proof shelters and in such positions gas-proofing is entirely practicable under all conditions.

Somewhere within the sector, probably in the neighborhood of the reserves, there should be stores of degassing materials with trained personnel available for degassing operations. The need for an efficient gas alarm and sentry system is obvious. It would be tied-in with the security measures normally taken. Frequent weather reports will assist the defender in forecasting the probability of enemy gas and smoke operations.

Personnel, especially anti-gas personnel, should be trained to watch weather conditions carefully and take note of prevailing wind currents in their small sectors.

Whether we are concerned with the protection of the landing party or of the beach defense, the chemical weapon introduces three principal requirements aside from proper equipment. These are careful training, perfect gas discipline, and a complete and well-integrated organization.

Part Three

Protection and First Aid

XII

THE GAS MASK

PROTECTION of a person against gas is simple and practicable. Only the ignorant need fear gas. Anyone willing to provide himself with proper means of protection (which are available), and to acquire a little information about how combat chemicals behave, can dismiss fear of gas from his mind and heart. Most casualties from gas are avoidable. The great problem in protection is training, discipline, and organization. The difficulty is in making the individual take the necessary measures that will guarantee his safety. Unfortunately a disastrous experience is often needed to teach the very simple lesson that all must learn.

It is obvious, in this day of highly developed weapons, that in order to fight a soldier must be protected. This was brought out most forcefully in the long period of stalemate during the First World War when it seemed that attack had failed. At that time the introduction of chemical warfare emphasized the necessity for a special type of protection that never before had been considered; protection of the lungs, eyes, and skin of the soldier against the direct action of chemical agents.

So far as the man in the street is concerned, protection is the vital part of chemical warfare. He can only strike back at an enemy by his efforts to speed production and otherwise

to lend his support to the armed services. Enemy gas can slow down the industrial effort more than any other single weapon. Combined with explosives, it can bring production to a full stop. Consequently, the worker has an interest in protection against gas equal to that of the soldier. Gas warfare will be directed against the centers of industry and transportation. The man behind the lines, therefore, must be just as able to protect himself against gas as the man behind the gun.

The entire subject of protection against gas is so extensive and so important that it is best to discuss it in several parts. For convenience, therefore, it has been divided into technical protection and tactical protection. These words technical and tactical protection, like so many we use, are only words and to the uninitiated do not express a real idea. They have come, through long usage, however, to have a definite meaning, and it is easier to use them and explain their meaning than to find new ones that speak for themselves.

Technical protection is concerned with methods, with equipment, and with the material factors entering into the problem. It is essentially of a passive nature, that is, it isn't much concerned with military action. It includes what the Army calls individual protection and collective protection. The first of these involves the methods a man may use to protect himself against gas—the gas mask, protective clothing that will keep out the blister gases, and the ability to recognize chemical agents in the field. Collective protection has to do with the measures taken to safeguard groups of men against gas—the construction of gas-proof shelters, the use of alarms, the removal and destruction of persistent blister gas on the ground and on equipment, the protection of food, water, and supplies.

Tactical protection, on the other hand, is concerned with movement and military action. It is not purely passive or static as is technical protection. The Army defines it as those active measures of security that assist the troops in carrying out their missions without excessive losses in gas casualties. It pertains primarily to the fighting arms, although today with the possibility of gas attacks on cities, there are many ways in which it might be applied to the industrial army.

The gas mask and protective clothing are the basic requirements for protection of the individual—every man must know how to use this equipment, when to use it, and how long. The gas mask gives complete protection to the face and lungs against any chemical we know of that can be used effectively in combat. During the World War the gas mask passed through many stages before it developed into the very adequate equipment which was furnished our troops. Since the war many improvements have been made until today Americans have what is almost certainly the best all-round gas mask there is in the world.

When the soldier put on a mask to protect himself from gas the glory of war was dimmed. No longer did he look the dashing hero. Instead, face covered with rubber and snout dangling in front, he looked like some queer beast from another planet. In his new armor, however, he was safe against the molecules that would have injured him otherwise. Since that time the gas mask has become a part of his normal equipment. He has not minded the appearance or worried about the loss of appearances. Perhaps the muck and mud of the trenches has destroyed his delusions of grandeur. The soldier, however, has insisted that his means of protection be comfortable, as well as protective, and he has demanded a device in which he can fight without undue loss of efficiency.

The question of protection against gas is a primary one in any discussion of war, for without a good gas mask the best-equipped and most skillfully trained army is helpless against an opponent armed with chemicals. When the first gas attack was made by the Germans against the Allies in 1915, there was no such thing as a military mask. Less than two weeks later a crude sort of protection had been attained in the form of pads of cotton saturated with a neutralizing solution, designed to cover mouth and nose. From then on the quality of the anti-gas apparatus was improved step by step.

The defense generally kept just ahead of the offense and at the end of the war our Army had a mask that stopped every gas the enemy could use. There were gas casualties to be sure, but they were not due to the failure of the mask. Failure to put it on in time or premature removal was responsible for most of the casualties. The best mask in the world is useless if it is not worn properly. Indeed, cases were reported of soldiers who had been rushed into the lines without sufficient training and were found wearing the gas mask on the chest, ignorant of the fact that it must be adjusted to the face. They thought that since the gas affected their lungs, the correct place to wear it was over the chest.

When America entered the war chemical warfare was two years old and had become well established. Each of the combatants had developed adequate protection against gas and each had carried on the development independently so that there was a great variety of masks in use. No systematic exchange of ideas existed among the Allies at this time. France, England, Russia, and the Central Powers placed their reliance on widely different appliances.

The United States had no gas mask nor any agency for providing gas defense. The hastily organized Gas Defense

GAS!
Low level attack with chemical spray.

U. S. Army Signal Corps

SMOKE
Infantry coming through the screen.

Division of the Army, working with the Bureau of Mines, decided that the British small box respirator offered the best possibilities. This respirator, universally known as the S. B. R., consisted of a box containing layers of charcoal and soda lime connected by a flexible tube to a facepiece of rubberized cloth which covered the entire face and was attached to the head by elastic tapes. It differed materially from French and German types in that it had what was termed the double line of protection. The air from the filter box passed to the lungs of the wearer through a flexible tube to a rubber mouthpiece held between the teeth. Exhaled air and saliva passed out through a valve in the metal angle joining the flexible tube to the mouthpiece. A pair of spring clips closed the nose. All air breathed entered the lungs through the filter. The facepiece protected eyes and face, and gave double protection to the lungs.

All Americans who served in the World War will remember vividly the S. B. R., for it was the type we used until late in 1918. There was hardly a wearer who did not curse wholeheartedly the clamps upon his nose, the mouthful of rubber carried between the teeth, and the fogging of the lenses in cold weather. Nevertheless, he was grateful for the complete protection given by this uncomfortable contrivance, the most effective gas mask in general use.

As soon as the S. B. R. was adopted by the War Department, work was started on 25,000. These were produced in record time, but proved faulty. Their failure, however, put our experts on their mettle and before long satisfactory box respirators were being manufactured by the million. The wartime type upon which production was concentrated was known as the R. F. K. (Richardson, Flory, Kops were the designers). It was introduced in February, 1918, and over

three million were made. The R. F. K. still was the British S. B. R., with improvements in comfort and effectiveness but with no radical differences.

Our research people recognized the importance of getting away from the uncomfortable nose clips and mouthpieces. More comfort was imperative because the use of mustard gas required that masks be worn for long periods of time. The French had developed for their artillerymen and certain specialists a respirator known as the Tissot mask. It was somewhat bulky but was comfortable and could be worn for long periods without difficulty. A box carried on the back contained materials to absorb the gases. This was connected by a rubber-covered metal tube to the facepiece, a thin mask of high grade rubber. The air passed through the box, in which charcoal and soda lime filtered out the gases, then through the connecting tube to the facepiece. At this point the tubing branched off into two parts, conducting the cool dry air across the eyepieces to prevent fogging. Exhaled air was expelled through a rubber outlet valve.

The Tissot facepiece was the best in comfort and design of any issued to troops during the war, but it was expensive, difficult to manufacture, and fragile. Safety depended upon the fit of the facepiece. It had no mouthpiece or nose clip.

Tendency in this country gradually swung toward the adoption of the Tissot facepiece, and, as a result, two Tissot type masks were developed, known as the A. T. (Akron Tissot) and the K. T. (Kops Tissot). About half a million of these two masks were made before the Armistice. Both facepieces dispensed with the objectionable nose clamps and mouthpiece, and included the Tissot principle of deflecting the incoming dry air across the eye lenses.

These new masks represented a radical departure from the

S. B. R., since they depended entirely on the fit of the face-piece to keep gas from the lungs. The design, however, assured a good fit, and the construction of the material was strong enough to eliminate danger of leaks from tearing. Increased comfort, clearer vision, and lowered breathing resistance justified the adoption of the Tissot type.

Meanwhile, work on the filter had kept up with other developments. All nations had selected charcoal as the principal material in the gas-mask canister for removing war gases from the air. Ordinary charcoal will take up gases readily but, when subjected to treatment by heat and steam, it is made still more active as an absorbent. This treatment gives it a very fine porous structure and, hence, greatly increased surface. At the same time compounds which interfere with its power to attract and hold gases are driven off. When air containing war gases is passed through granules of activated charcoal, the molecules of the gases are adsorbed, that is, attracted and held on the surface of the pores somewhat as iron filings are held on the surface of a magnet. The air is not adsorbed and passes through the gas-mask canister and is purified.

The charcoal in use until recently, however, did not hold tightly enough certain volatile acid gases, such as phosgene. It was found necessary to mix with it soda lime, a material with a high capacity for fixing these gases. Charcoal and soda lime formed a splendid team. The soda lime acted principally as a reservoir for the permanent fixation of the more fugitive gases, while the charcoal furnished the necessary activity for all gases, as well as high capacity for holding less volatile ones such as mustard. Where one was deficient, the other was adequate. Thus, while the capacity of charcoal was decreased by heat and moisture, the soda lime became more reactive.

When America started making respirators, a canister larger than the British was made, since it was feared that the charcoal we had was inferior. Actually our charcoal proved so much better than that used by our Allies that it was possible greatly to reduce the size of later canisters. Our national tendency to credit foreign materials and methods with greater virtues than our own is rarely justified.

The use of the Blue Cross shell by the Germans made it necessary to have a mechanical filter in addition to the absorbing chemicals. Blue Cross, as noted above, was an irritant solid which added to high explosive artillery shell was, on explosion, dispersed in the air in very small particles. These, being solids, were not held by charcoal or soda lime and passed right through the canister, causing sneezing and nausea to the wearer. Cotton pads, layers of turkish toweling, paper, and cellulose were used in the gas masks to filter out these small particles of irritant smoke. Felt was found to be the most effective filtering material. As the war came to a close, felt was being incorporated in the experimental canisters that were to be used with post-war masks.

During the year and a half America was at war, over five and a half million gas masks were produced. With the A. T. and K. T. masks we possessed the best that there was in comfort and safety. When it was decided that these types were not well adapted to the large-scale manufacture demanded by our rapidly growing Army, development was started to produce a simpler facepiece that would combine all the advantages of the preceding types. The result was the 1919 mask, production of which began just before the Armistice.

The 1919 mask was made from a special rubber compound which came in long sheets, on the outside of which cotton

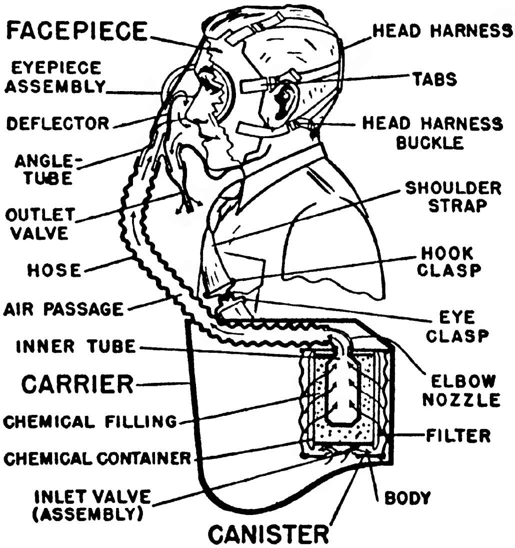
stockinette was vulcanized. The facepiece was died out of the flat sheet, in such a design that a single seam at the chin of the completed mask produced the proper shape to fit the face. Eyepieces were made of non-shatterable glass, similar to that later used in automobile windshields. They were kept clear by the Tissot principle of deflecting cool dry air across the lenses as it was breathed in. A rubber deflector where the air entered the facepiece accomplished this.

The blue canister, which formed a part of the 1919 gas mask, provided the most complete protection attained up to that time. It contained charcoal and soda lime of a higher activity, surrounded by a mechanical filter of felt to remove the fine particles of irritant smokes.

The design of the carrier for holding the respirator was a complete departure from all previous ones. With a few minor changes, it is the same as now in use. It is an irregular shaped canvas satchel provided with adjustable shoulder and waist straps and is carried under the left arm. The mask is withdrawn through an opening that comes just above the waist and is adjusted to the face without change of position of the carrier as was necessary with the former wartime satchel.

The side carrier is the result of the demands of the soldier for a simple and comfortable container for the mask. The 1917-1918 satchels were carried in two positions–slung over the shoulder and worn at the side in rear areas where there was slight danger of gas, and raised to the chest in what was called the alert position when near the front lines. Considerable instruction was needed to assure proper carrying and adjustment of the two-position satchel, and the position of the gas mask on the chest was an awkward one. Men complained that when crawling over the ground while under enemy fire, the gas mask on the chest hampered them

and did not permit them to get close enough to the ground. The desire to be as close to mother earth as possible under such circumstances is easily appreciated. Machine-gun bullets can make three inches seem mountain-high. The side carrier did away with these difficulties. It is always in the alert posi-



SERVICE GAS MASK (4.6 pounds)

tion, does not interfere seriously with movement, is more comfortable to wear, and better protects the entire mask from moisture and other harm. The corrugated rubber tube which connects canister and mask was made nearly twice as long when the carrier was dropped to the side position.

The only thing besides the gas mask in the carrier has been the anti-dim can which contains a small stick of special soap and a piece of cotton flannel for cleaning the eye-

pieces. The anti-dim stick leaves an invisible film on the lenses which helps to reduce fogging.

While the gas mask in use today seems to differ little in outward appearances from the 1919 mask, it is really a greatly improved apparatus. Noteworthy progress has been made in providing better gas masks. There have been many important improvements in comfort and dependability which are apparent to the wearer, but of even more importance, although not so apparent, is the progress in ability to manufacture on a large scale, at reduced costs and with increase in life.

Comfort when applied to the gas mask is purely relative. No one has ever produced a mask that is a joy to wear. We wear them because we have to. Comparative comfort is progress, and comparative comfort has been attained in our respirators of today.

The use of the voice is necessary and it was not easy to converse or give commands while wearing the mask. The Navy, especially, needed a mask that would permit the transmission of the voice through speaking tubes and ship telephones. To meet the demands of users, the diaphragm gas mask was designed. It is similar to the regular service type, except that the angle tube where the hose joins the facepiece is made to include a diaphragm of thin sound transmitting material protected by perforated metal. Over the telephone voice transmission in the diaphragm mask is slightly improved. The small increase in voice transmission provided by the diaphragm did not justify the increased effort in production and complication in supply and the diaphragm mask was destandardized by the army in 1943.

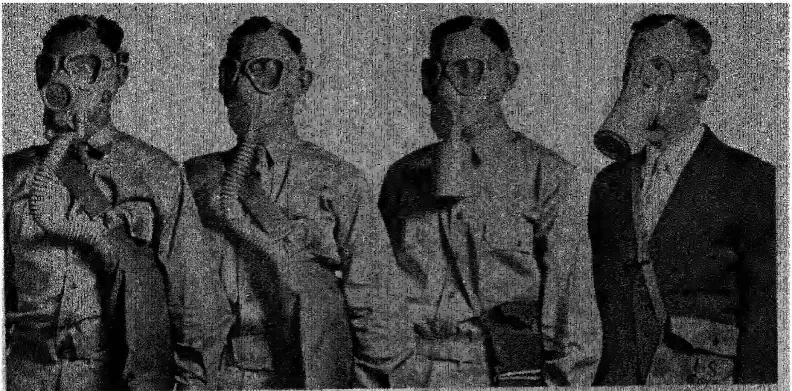
In 1925 a change was made from sheets of calendered rubber to molded face blanks. Molded stock is of longer life and more uniform quality. The present facepiece

which is completely shaped in the mold was adopted. This provides the ultimate in comfort and convenience. One of the most important features of the new mask is that it is so designed that one universal size will fit nearly all faces. Gas sergeants appreciate this, for the old types came in five different sizes and fitting was sometimes difficult. About five per cent of the faces cannot be fitted with the universal mask, which is marked with a U. One per cent, large size, marked "4," and four per cent, small size, marked "1," are issued to the Army to fit the extra large and small faces. No one will escape the draft because he can't be fitted with a gas mask.

The eyepieces of the latest type mask are shaped to give the greatest possible vision to the sides and below. In previous models it was not possible to see the feet without ducking the head.

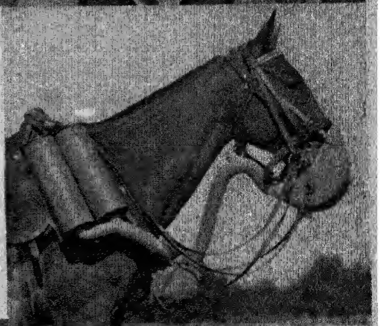
The comfort of the gas mask depends upon the ease with which one may breathe as well as upon the fit of the facepiece. Resistance to breathing is centered to a considerable extent in the canister. It is not easy to increase the effectiveness of the canister without increasing the difficulty of drawing air through it. Every change in the chemical contents or the mechanical filter must be made without making the resistance to breathing so great that the wearer of the mask has to make an effort to fill his lungs.

The construction of the filter in the present canister is one of the greatest accomplishments in post-war gas mask development. A new type filter makes use of a cheap cellulose product of nearly unlimited supply. This filter, which entirely replaced the felt filter, costs only a small fraction of the felt filter. It has a lower breathing resistance and, at the same time, gives better protection against the irritant smokes.

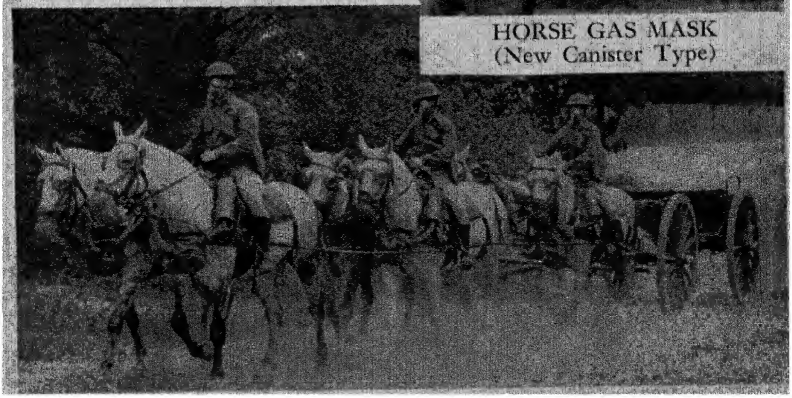


THE PRINCIPAL STANDARD TYPE MASKS

Left to right are: the diaphragm mask, the service mask, training mask and noncombatant mask.



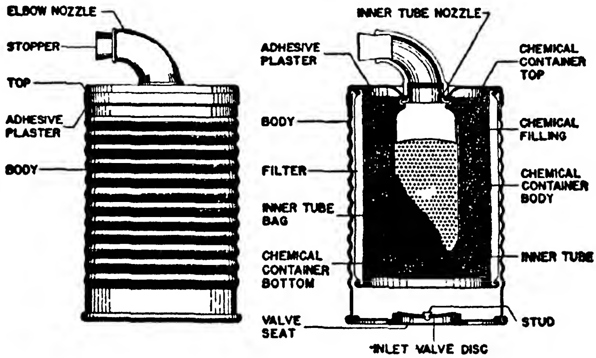
HORSE GAS MASK (New Canister Type)



HORSE ARTILLERY WITH NEW TYPE HORSE MASKS

Airplane mustard spray will affect skin of men and horses unless protected. These men and animals have gas masks but no protection for skin.

Although service gas masks are not suitable for use by firemen, since they do not protect against carbon monoxide, they have been used because they filter out smoke. Such use is dangerous. The new filter will remove even the fine smoke from burning electrical insulation such as bakelite and will remove tobacco smoke from the air easily. It is indeed the most effective filter for removing smokes of all kinds that has ever been provided for the gas mask. It must be em-



SERVICE GAS MASK CANISTER

phasized, however, that no protection is given against carbon monoxide which is likely to be present where there is smoke.

The quality of the chemicals has been improved. The activity of charcoal has been increased many times. The new charcoal is now so reactive that it has been possible to eliminate the soda lime previously used and, of even greater importance, to use less charcoal. A smaller and lighter canister is now possible without sacrifice of protection or increase in breathing resistance. The breathing resistance of the present standard canister is much less than that of the canisters of the early 1920's.

The present service canister is an oblong-shaped metal box containing a combination gas and smoke filter. This filter is a perforated metal container, oval in shape, filled with charcoal. The outer surface of the perforated container is covered with a specially prepared fibrous material which filters out the smokes. It is this material that replaced the felt. Air enters the canister through an inlet valve at the bottom and is drawn first through the smoke filter, and then passes through the charcoal to a central wall and reaches the facepiece through a rubber tube as purified air.

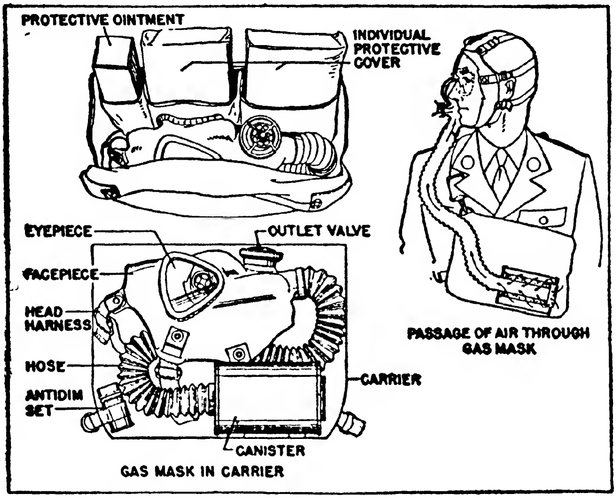
Today there are three standard Army gas masks; the service mask, the lightweight service mask, and the assault mask. There is also an optical mask of special design for use with optical devices. The optical mask permits the use in gas attacks of fire control and similar instruments which cannot be adjusted to the eyes with the standard gas masks.

The speed and mobility demanded in the present war has brought a requirement for a reduction of weight of all military items. A lightweight service gas mask is now being issued to elements of our army. This mask, like the service mask, has a rubber facepiece, canister with connecting hose, and a carrier.

Its principal value lies in the much lighter weight and compactness compared to the service gas mask. For example, the canister which is similar to that used with the training mask, is approximately one-half the weight of the standard canister and gives about the same order of protection. This saving in the overall size and weight of the lightweight mask increases the ease with which it may be carried and handled, and makes it especially suitable for amphibious operations. It may be carried with comfort by the tank driver, who finds himself cramped in his bucket seat by the side carrier. I know

the discomfort of the side carrier in the tank for I've driven one while wearing the mask and found it necessary to detach the side carrier and swing it round to my lap.

The mask is of rugged construction and affords ample protection after normal rough handling in the field. It can be



LIGHTWEIGHT SERVICE GAS MASK (3½ pounds)

worn for long periods of time without discomfort and will not interfere with normal combat activity. An additional advantage is that the carrier is provided with pockets for auxiliary items such as the protective ointment, individual protective covers, and detector paper.

The lightweight service mask still is somewhat heavier and bulkier than is desired and a new assault-type mask, much lighter (2¾ pounds) and more compact, is now being produced. This mask has a light but very efficient canister

ASSAULT GAS MASK

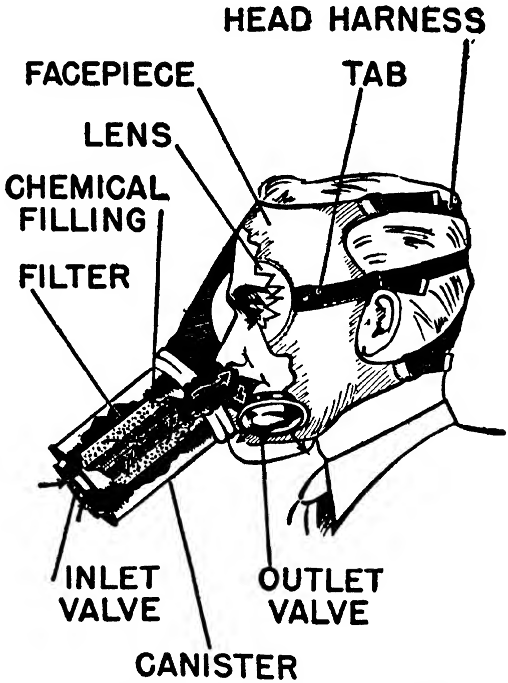
attached directly to the left side of the facepiece, and a carrier thoroughly waterproofed. It is carried suspended from the shoulder or from the waist strapped to the leg.

The training mask was developed to provide the Army with a cheap and lightweight gas mask for training purposes. It has the service facepiece but is otherwise much different. The eyepieces are of tough transparent plastic. The canister, which is about the size and shape of a small tin can, hangs directly from the facepiece. There is no hose tube. The mask when not in use is carried at the left side in the carrier, a canvas bag with an adjustable shoulder strap. The training

mask is intended for training only, but it gives adequate protection against all the standard chemical agents.

In order to assure that necessary preparations are made for civil defense against enemy gas, a noncombatant mask has been designed by the Army. It is similar in general appearance to the training mask, being of the snout type with canister connected directly to the facepiece. The facepiece is of simpler construction of either rubber or a special resistant fabric with extra large plastic eyepieces. The canister is much like the training type. Cost is of particular importance in a civilian

mask and this factor of course must influence the kind of mask that is produced.



NON-COMBATANT GAS MASK

The requirement for civil defense differs materially from that of the armed services. The Army must have a mask that is stout enough to stand the hard wear of a campaign, and that will protect for long periods of time against continued heavy concentrations of gas. The soldier may not be able to move out of a gassed area but may have to stay there and fight for a long time. The service mask must permit extreme exertion and not interfere with use of weapons. In the case of the civilian mask the principal purpose is to get the wearer

out of the gassed area and to a bomb- and gas-proof shelter without injury. Resistance to heavy concentration for a long time is not of primary importance. Simplicity is essential. Since these masks must be supplied by the million, the cost must be reduced to the lowest possible figure consonant with safety and effective protection. Those engaged actively in civil defense measures, such as firemen, first-aid personnel, and repairmen for the utilities, need a more rugged mask of higher capacity for removing gas and will doubtless be furnished with a service type.

Of course the appearance of the gas mask has always caused much amusement to the soldier. There is no doubt that it is a very weird-looking affair. I remember a story that was current in France during the First World War. A gas attack had taken place and the gas had finally dissipated. As one soldier came out of a dugout another called to him, "Hey! Buddy! The gas is gone—take off your mask." The other soldier replied, "It is off." At which the first one said, "Then for the love of the saints put it back on."

The problem of providing gas masks for young children has been a matter of much concern to the civil defense authorities in all the warring countries. A three- or four-year-old cannot be blamed if he becomes terrified at this strange and rather awful-looking piece of equipment. Consequently, various devices have been used. One that has been considered is a mask in the likeness of that universal favorite, Mickey Mouse; wearing such a mask, a child may find the gas attack becoming a game for him and thus be cajoled into protecting himself.

The problem of making parents recognizable to their children while wearing the gas mask has been partially met by

increasing the size of the eyepieces and making more of the face visible. There is, however, much improvement required here and it might be necessary to go to a completely transparent mask. Such a mask was produced and sold in Germany in the years before the war. It is open to the objection that it is difficult to fit such a mask properly to the face and also that the transparent material is brittle and not likely to stand hard usage. The protection of a baby is secured by placing it in a gas-proof bassinet or cradle. Here again it is important to prevent terror on the part of infants who frequently fear anything which closes them in. A transparent gas-tight cover seems satisfactory for this purpose. A gas-mask canister permits filtered air to pass inside when pumped by a small bellows. Another device is the "infant respirator" consisting of a hood and coat combined in one garment. It incloses the head, shoulders, and arms, and is closed at the waist by a drawstring, thus permitting the baby to get its hand to its mouth. Ample vision for mother and baby is provided by a large window. Air is supplied through an outside canister by means of a bellows, which must be pumped regularly. These respirators are designed to include a separate carrier to fit the back of an adult. The garment is large enough for children up to six or seven years of age. Noncombatant masks should not be given to children less than four years of age.

The canisters of the gas masks which have been described in this chapter protect only against chemical warfare agents. These masks do not protect against certain gases which may be met with in industry or otherwise but which are not used in war. Carbon monoxide and ammonia, for example, are gases which the military and civilian masks do not protect against and which are most likely to be encountered in a

non-military way. Carbon monoxide is not a warfare gas but it is present wherever there is a fire or an explosion. After the last war many of the Army gas masks were used in fire-fighting with the result that many people were overcome by carbon monoxide. For the same reason the ordinary masks should not be used to enter a refrigeration plant or other place where ammonia gas has been leaking.

Many deaths have also occurred from wearing masks in tanks or tunnels where there is not enough oxygen. The gas mask does not supply oxygen or make air. Consequently, it must not be worn unless there is plenty of oxygen present. Mine shafts following an explosion, the holds of ships, tanks containing volatile liquids, are all places where there is likely to be a deficiency of oxygen. The gas mask should never be used in such places. Instead, oxygen breathing apparatus or a face mask connected to the outside air with a long tube through which air may be pumped should be used. Special canisters may be obtained from certain commercial firms which do give protection against some industrial gases, such as ammonia, carbon monoxide, hydrocyanic acid gas, organic vapors and smokes. These canisters, however, are constructed to take care of a special situation, and are only suitable for that use. They can not safely be used for war gases.

The Army does provide another type of respirator which has been found necessary in the dry sections of the country where the dust is heavy. Several types of dust masks have been made standard and are issued to such organizations as motorized divisions and armored force units. These are simple filters which cover the mouth and nose and keep out the dust.

There is a limit to the protective capacity of a gas mask

but I never saw that limit reached in the last war. It is possible that men wearing the gas mask were overcome by extremely heavy concentrations of gas passing through the canister, but there was no record of this.

The gas-mask canister protects against concentrations of war gases of one per cent by volume. Such a high concentration as this would rarely if ever be encountered in the field except in the immediate vicinity of the explosion of gas shell or in a dugout when a gas shell bursts at its entrance. I think it is reasonable to assume that in such a case the man would probably be injured by the fragments of gas shell. To be on the safe side, the Chemical Warfare School recommends that men "even though wearing masks, should move quickly from the immediate vicinity of such explosions, holding their breath while so doing." It is difficult to imagine a man standing still under such conditions. The chances are pretty good that he would take distance as rapidly as possible when the shells started to fall close by.

Animal Masks

In spite of the changes brought about by mechanization, with scout cars and tanks taking over many of the duties of cavalry, and armored artillery taking the place of most horse-drawn batteries, armies still have many horses and mules, and therefore have the responsibility of protecting them from gas. The Germans, for example, have some 800,000 horses in their army.

Ever since the First World War all armies have had gas masks for their animals. Horses are so constituted that all their breathing is done through their noses. In making a gas mask for a horse, therefore, it is only necessary to assure

that purified air is supplied to the nostrils. The World War type of horse mask has been improved greatly and is still available although obsolescent. It consists of a cheesecloth bag which covers only the nostrils and upper jaw. Horses' eyes are not easily affected by tear gases and, therefore, the mask does not cover them. The mask has a canvas mouthpiece which goes into the horse's mouth and prevents the cheesecloth from being bitten through. When in place, the bag extends several inches beyond the horse's nostrils to permit easy breathing.

The World War mask, however, has been largely replaced by a type having a canister and designated as M4 and M5 horse gas mask. The canister masks are similar in principle to the masks used by men. On each mask a muzzlepiece of moulded rubber is shaped to fit the nose and mouth, and provides an airtight seal. A pair of canisters removes both gas and irritant particles from the air. The M4 mask has a canister suspended on each shoulder of the horse, while the M5 has both suspended on the off (right) shoulder in order to facilitate carrying a rifle on the left side of the saddle.

The muzzlepiece is designed to fit all sizes of horses and mules. The aperture for the muzzle is considerably smaller than the muzzle of the smallest horse, and the gastight seal is obtained through the elasticity of the rubber. An embossed line is molded around the lower edge of the aperture and the rubber may be cut along this line if it is necessary to fit horses with large muzzles. In the case of horses with extremely large muzzles it may be necessary to cut an additional strip a sixteenth to an eighth of an inch around the existing aperture. The muzzlepiece has an inlet valve as part of the inlet tube and an outlet valve for exhaled air and drainage. Adjustable leather straps with harness snaps are attached to the muzzlepiece in order to secure it to the halter.

The horse mask is intended principally for draft animals when they are used to haul supplies and ammunition through a gassed area. In the case of unloaded or cavalry mounts it is better to remove them from the gassed area instead of attempting to put masks on them. Some will take the mask without much trouble, but others resist violently and a small fraction cannot be forced to take the mask.

Horses are more susceptible than men to chemical agents which attack the skin. In all other cases horses can stand a much higher concentration of gas than human beings, and they are practically not affected at all by lacrimators since they do not have tear ducts.

The entire skin area of the horse is affected by mustard type agents. The most vulnerable parts are those where the skin is tender and where sweating is most active. Horses do not have tear ducts like man which accounts for the fact that their eyes are not affected by tear gases. They are, however, sensitive to mustard type vapors, and liquid mustard will cause serious injury and destroy sight.

The foot is also a very sensitive part of the horse's body and it is the most likely part to pick up mustard type agents. Consequently, mustard burns on the horse's feet probably cause most of the chemical injuries. The animal may be permanently disabled by moving over ground contaminated with mustard type agents through injuries to the fetlock, coronary band, and sensitive parts of the hoof between the bar and the frog.

Another source of serious danger to animals is contaminated forage and water. Obviously the animal should be prevented from grazing on pastures on which there is reason to believe mustard-gas shells have fallen or to drink water from shellholes or ponds where chemical shells have

exploded. Even small amounts of mustard gas taken into the body in this way will have serious effect on the entire digestive tract and mouth and may make it necessary to destroy the animal.

When it is not possible to keep the horse away from the gas either by getting him out of gassed areas, or by placing him in a stable or shelter which is protected against gas, the mask should be adjusted in order to protect the lungs. In addition, the eyes should be hoodwinked to protect them from vapor or spray if mustard gas is being used and the body should be covered with a blanket. In selecting picket lines, or places where one or two horses are to be tethered in the open, consideration should be given to avoiding areas likely to be gassed or which already may be contaminated with light concentrations. On the march it is necessary for mounted parties to detour around contaminated areas even when men might go right through without serious danger by using their protective equipment. During the First World War horse boots were used to some extent to keep mustard gas from the feet and lower legs, but such equipment is difficult to adjust, wears out quickly, and is not practical.

In the American Army dogs are not used and so there has been no problem of providing a dog mask. I have seen, however, masks supplied for dogs in the German Army. They were of impregnated cloth similar to the horse mask in principle except that they covered both jaws as well as the nostrils since a dog breathes through his nose and mouth. Photographs of German equipment showed dogs wearing goggles to protect their eyes against tear gas.

You probably would not expect to find a gas mask for birds but, believe it or not, the Army does provide protection for that very useful and important messenger—the car-

rier pigeon. There is not much danger that the pigeon will be injured by gas when in the air since it will fly high enough from the ground to escape the vapor. It is believed that mustard type agents will cause little injury to the birds since the feathers should provide natural protection for the skin. They would be injured by eating grain contaminated by mustard gas. A gas mask for a pigeon seems a very strange piece of equipment and, of course, no attempt has been made to provide individual protection. Instead of putting a mask on the bird, the bird is placed in a protected cage or basket. The pigeon basket is protected by a bag of flannelette which is treated by chemicals similar to those used in the horse mask. The bag fits tightly over the pigeon cage so that all air that reaches the inside must come through the chemically treated fabric.

Pigeon lofts are protected by sealing up all holes and covering ventilation spaces with chemically treated gas-proof blankets. It is a rule that when the birds cannot be protected they must be released at once.

XIII

PROTECTION OF INDIVIDUALS

THE protection of an individual involves much more than the knowledge and use of the gas mask. Blister gases which burn the skin have made it necessary to protect the whole body against gas, since the mask protects only the breathing apparatus, eyes, and face. Blister gas may be prevented from reaching the body by shutting it out mechanically by wearing impermeable protective clothes, or by destroying it chemically before it can reach the skin by treating clothing with a neutralizing chemical.

During the First World War, the first method was used. It was found, however, that men could not work or fight for any length of time encased in impervious clothes which prevent circulation of air. I have seen our men in France dressed in this sort of clothing tear it off while working in an area reeking with mustard gas because they couldn't stand the discomfort any longer. Such suits are impervious to liquid or gas and, therefore, prevent the escape of heat and water vapor from around the body. Consequently, they are very difficult to wear for more than a short time—say, fifteen minutes to half an hour in warm weather.

A complete impermeable suit consists of impermeable outer and chemically treated undergarments. The outer garments are coveralls made of coated material such as alligator cloth

or oilskins, with an attached hood of the same material. These keep out mustard gas mechanically. Underneath the coveralls long underwear impregnated with chemicals is worn. The legs of the impervious suit are buckled tightly over shoes treated with special "dopes." Socks are impregnated. Rubber boots of a special type of rubber highly resistant to mustard penetration may be substituted for the shoes if the trousers are pulled on over the boot leg. Gloves of mustard resistant rubber are worn over treated cotton gloves. Gas masks complete this equipment. Unfortunately, however, a man can not wear it very long if he has to move about actively or do much work. Frequent shifts are required. The use of the impermeable suits therefore is confined to personnel who man exposed guns that must fire even when subject to direct spray attack, or to those engaged in gas manufacturing or filling operations. The latter may encounter large pools of liquid vesicant caused by accidents, or be subjected to splashes from broken pipes or tanks.

A practicable protective clothing permeable to air but treated to carry a neutralizing chemical within the fabric has been developed since the First World War by the Chemical Warfare Service of our Army. This clothing protects effectively against vapor or light spray of the blister gases.

Garments must be designed to cover all parts of the skin not covered by the mask. Open spaces in ordinary clothes, for example around the neck, wrists and ankles expose those parts of the body to the gas. Buttons do not provide a tight closure and gas may penetrate through spaces where the closure is not tight. Probably the most satisfactory design for all-around protection is a coverall which fits closely around the neck, wrists, and ankles.

For complete protection treated underclothing as well as

GAS ALARM—THE NEW ARMOR

Soldier completely equipped with mask and permeable protective clothing.

U. S. Army Signal Corps

ENTRANCE TO GAS PROOF SHELTER

(Blanket door construction)

GUN CREW PROTECTED AGAINST GAS

Firing 75-mm. gun while wearing mask and permeable protective clothing.

outer clothing is required together with a hood, leggings, special shoes, and gloves.

Permeable protective clothing is not difficult to wear nor is it uncomfortable. It differs very little from ordinary clothing and except for a slight odor and different "feel" the wearer would not know he was wearing protective clothing. I have worn it many a hot Maryland July afternoon, part of the time in a strong mustard-gas atmosphere, and moved about actively. Aside from the discomfort of heavy underwear in the midsummer heat it was not a handicap. Our permeable protective clothing is practicable and effective.

Woolen uniform outer garments furnish some protection against mustard gas even though not chemically treated. Cotton garments are less effective than wool. Mustard liquid penetrates thick wool in ten to fifteen minutes, cotton uniform material in five to ten minutes. Vapor will penetrate clothing gradually. The liquid will penetrate leather shoe soles in about twenty-four hours.

In the Army, protective clothing is supplied in standard sizes by the Quartermaster. Since leggings must be put on over a thickness of heavy underwear, socks and coveralls, the soldier requires a size larger than he regularly wears.

If either permeable or impermeable clothing has been only slightly contaminated, it may be made wearable by exposing it to sunlight and a free circulation of air for one or two days. If only exposed to light concentrations of vapor it will be safe if aired out for an hour or two in the sun or overnight. In all cases after use, protective clothing should be hung up to aerate and to dry free of perspiration.

Impermeable clothing cannot be laundered, nor can blister gas be removed so that it is safe to wear. These garments must be thrown away if contaminated by more than a light vesi-

cant spray. Permeable clothing can be successfully cleaned by usual laundering methods.

If garments have been heavily contaminated, they should be laundered and reimpregnated. Reimpregnation is performed in the Army by the Chemical Warfare Impregnating Company or by chemical warfare "service" personnel, using the Field Impregnation equipment.

The most recent addition to antigas equipment is the Individual Protective Cover. Two of these covers are furnished to each man in a theater of operations. They are carried in the side carrier with the service mask. New type lightweight gas mask carriers have a pocket for the covers and for protective ointment. The protective cover is a light cellophane cape folded into a compact package about 6 inches by 4 inches by ½ inch. It is for use in airplane spray attacks and may be shaken out and pulled on over the head in a few seconds. It is used for the same purpose as an umbrella—to shed the drops, and when the spray attack has passed the contaminated cover is thrown away. Built with plenty of room, the gas mask can and must be adjusted underneath the cover which does not protect against the vapor. It is roomy and thin enough so that a man can manipulate the trigger of a machine gun while wearing it. There is room enough within the cover to allow the rifleman to aim and fire his rifle. This of course will blow a chunk out of the cover but the remaining coverage is reasonably ample.

If the protective problem consisted merely in furnishing a gas mask and protective clothing, it would be a very easy one to solve. The solution, however, is not so simple. Some gases, especially non-persistent casualty agents, are so deadly that one or two good breaths will kill when delivered in high concentrations. A man, therefore, must be able to put on his

gas mask before he takes one breath of the poisoned air.

Another problem that complicates protection is the mustard-gas type of agent. Sprayed from an airplane, extremely high vapor concentrations result in the air. Moreover, liquid spray may penetrate our protective clothing, effective as it is. When chemicals are used spray will present the most difficult problem in protection.

The use of mustard type gases demands that troops be protected from heavily contaminated ground and undergrowth. Men marching along a trail which has been mustardized may brush against liquid mustard held on the leaves, twigs, or grass; they may walk on ground which has been splashed with mustard gas. This will be a definite hazard *unless men move through the area quickly and with care. We must not exaggerate the effect of H, however, nor let it deter us from accomplishing a mission.* Contaminated areas can be crossed without too great difficulty or danger if reasonable precautions are taken. Men should wear masks and pick their way avoiding obviously heavy concentrations, as for example in the vicinity of a shell, mine, or bomb burst. They should avoid undergrowth and high grass. They should move quickly through the area. One danger of a gas such as mustard is that it is effective in low concentrations, and that it is barely perceptible to the sense of smell; in fact exposure to it destroys the sense of smell. The highest kind of training and discipline is necessary to combat this.

Here is the point: After we have found out what we have to protect against and after we have been provided with equipment for protection, we come to the most important part of the protective problem. The individual must become thoroughly familiar with his gas mask, know what it will accomplish and how it should be used and cared for. Next, he

must develop skill in its use. At the same time, confidence must be developed in him that the equipment will give complete protection, and the unreasonable fear of gas which exists in the case of the average untrained man must be removed. All of this is accomplished by training and this training takes time, much time. It is important especially in civil defense training to teach confidence in the mask. This is best accomplished during gas chamber work—that is, by drills and tests in an atmosphere of real gas. Civilian drills should be conducted in tear gas. Soldiers should be trained in a toxic gas such as chlorine.

The gas chamber is simply a room or other enclosed space into which may be introduced a chemical agent which is readily detected at low concentrations. If the facepiece does not fit correctly, or is adjusted improperly, warning is given in the gas chamber without any more serious effect than a momentary irritation. The gas chamber serves several purposes: It tests the fit and adjustment of the mask. It gives practice in the adjustment of the mask under simulated field conditions. It promotes confidence in the mask. It dispels inordinate fear of gas.

Any reasonably airtight room or enclosed space of moderate size will serve as a gas chamber. Under war conditions, where it is necessary to train large numbers of men in a minimum length of time, a gas chamber of adequate capacity should be constructed. It should be a separate building divided into two rooms, each about twenty-five feet square and eight or nine feet in height (the exact dimensions are not important). The building should be somewhat isolated, 100 to 200 yards removed from any place where men are likely to be assembled for other training. Each room should be well lighted, naturally and artificially. Each room should have two

close-fitting doors which open out, and should be equipped with an electric fan to facilitate clearing of gas. The advantage of two rooms is that personnel may be exposed first to one gas (a tear gas), then to another (a toxic gas, such as chlorine), without waiting to clear the chamber of the first gas. A considerable saving of time is thus effected.

During the last war I used a tiny outhouse at Camp Taylor, Kentucky, as a gas chamber and processed several thousand men through chlorine concentrations without difficulty before a standard chamber was built. Several layers of newspaper were pasted over the walls and ceiling, and cracks in the floor were ignored. The little room had only one door and by crowding would hold about twenty men.

The most suitable tear gas for this purpose, and the one generally employed, is CN. It is easily volatilized with an empty tin can and an issue candle. Only a small quantity of CN is required. CN grenades or candles must not be used in an enclosed space such as a gas chamber, since a dangerous concentration of tear gas and also of carbon monoxide generated by the burning powder may result. CN for gas-chamber exercises is provided in small capsules, two of which are sufficient for a chamber of 2000 cubic feet. If it is not furnished in capsules, a pinch of the substance sufficient to cover a dime should be used.

Having drilled men in the use, inspection, and care of the gas mask, the next steps in the training are the final test of the fit of the mask to the face of the wearer, demonstration of the efficiency of the mask, and practice in mask adjustment in a gas atmosphere. The gas chamber is used for these purposes.

The removal of an unreasoning fear of gas is not always easy, but all chemical warfare training should give consideration to this fear factor. Soldier or citizen must learn that

proper use of anti-gas equipment will give complete protection, and at the same time gain an understanding of the power of the gas weapon.

Invariably, when a class of men or officers go into the chlorine chamber, there is a decided slowing up and confusion in adjustment of the mask. No matter whether they are able to get the mask on quickly and skillfully outside the chamber, just as soon as they get into the chlorine and have to put on their masks in what they know is a toxic atmosphere, there is confusion, hesitancy, and occasionally fright. There is not much difficulty in teaching a man how to put the mask on, but there is difficulty in training him so that he can adjust his mask properly in a gas attack.

During the First World War it was true, and it will be true in this war—the fear of gas is a very real fear on the part of the average individual. It is a fact that some of the gas casualties listed during the First World War were really not gas casualties, but were due to malingering or fear. Nevertheless, the men went to the hospital and were at least temporarily out of action. For the time being they were ineffective and gas had accomplished its mission psychically if not physically.

There is something mysterious about the effects of gas even to those who are acquainted with it. The explosive shell bursts, the man dodges and falls to the ground, and as soon as the burst is over, if he is alive and unwounded, he picks himself up and thanks God he is whole. After the gas shell bursts, however, he is still uncertain as to whether he has been affected. He is not sure for several hours, in the case of mustard gas, whether he has been burned by it. In the case of phosgene which has a delayed action the same thing is true. This has an effect on a man's morale that the explosive does

not produce. It is a fact that has to be recognized and is something that calls for tightening up in discipline.

Mask-adjustment drill becomes very tiresome and monotonous if unduly prolonged. Frequent brief drill periods of fifteen to twenty minutes give the best results. Such drills while essential are, however, not sufficient. After men have mastered the mechanics of mask adjustment they should thereafter be required from time to time to wear gas masks in the performance of their normal duties. The periods of wearing the masks while performing such duties should be gradually increased.

It safely may be assumed that when chemicals are used on a large scale, men will have to work and march for long periods in the gas mask. As I have pointed out, efficiency is cut down while wearing the mask. It has been found that men can march only about two-thirds as fast masked as they can without the mask for the first hour of marching. If continually masked, their speed is cut to one-third of what it was originally. If, however, men are properly trained in wearing the mask, an important part of their efficiency will be restored. Although the breathing resistance of the mask is not great, there is, nevertheless, a definite effort required in breathing in a gas mask. The lungs must be conditioned to this. Practice in wearing toughens the breathing apparatus.

Soviet Russia's great military accomplishments in the past year are the result of long years of preparation. Here are some reports made public in 1935 which show what was being done then to toughen and prepare the Soviet troops. These reports indicate a significant attitude toward gas-mask training and may also help to explain in part why the Russians were able to halt the Germans when it seemed they were invincible.

Fourth Division. During the inspection of this division competitions were held between the various units; companies composed of picked soldiers from the 10th and 11th Infantry Regiments made a forced march of 20 kilometers [about 12½ miles] in 3 hours and 13 minutes wearing gas masks. Not a single soldier failed to complete this march.

Tenth Division. The 20-kilometer march with gas masks was completed by a team from the 28th Infantry in 3 hours and 38 minutes; by one from the 29th in 3 hours, 32 minutes; and by one from the 30th in 3 hours and 27 minutes. . . .

Other Military Districts. A Company of the 132d Infantry of the 44th Division in the Ukrainian Military District marched 20 kilometers while wearing gas masks in 2 hours and 40 minutes; there were no stragglers. A battalion composed of units of the 74th Division (North Caucasian Military District) made a similar march in 3 hours 40 minutes in the mountains during a simulated air and gas attack under difficult conditions. In the Caucasian Red Banner Army excellent results in marching have been attained. One unit made the usual 20 kilometers march in 2 hours 14 minutes during which it had to ascend 500 meters.

All should be impressed with the fact that it is to their interest to care for and become proficient in the use of their gas masks. Ingenuity and imagination in including use of the mask with other activities, will help to promote this attitude. It will pave the way for the strenuous and prolonged periods of wearing the mask which are essential in fitting men to face the gas situations that they may expect in war.

Along with the training in the gas mask, a knowledge of the gases themselves is required. A man should be able to recognize the war chemicals by their characteristic odors, and training in the identification of agents is an important part of the protective scheme. It is best accomplished by exploding small tubes of diluted agents in the open so that students

can recognize the odors without danger of getting too much. Gas identification sets are provided for this purpose in the army. Where it is not possible to use this method there is an Instructional Gas Identification Set, popularly known as the Sniff Set which contains eight four-ounce glass bottles filled with charcoal, saturated with a chemical agent. One or the other of these sets should be available and should be used for the instruction of all military personnel. Civilians should be trained with the Sniff Set. I believe it desirable to have sniff bottles available in central places so that our people may become acquainted with the odor of the various gases. Each Post Office might have a Sniff Set for this purpose.

Trained personnel, such as gas non-commissioned officers and gas sentries, are taught not only to identify each agent positively, but also how to estimate the concentration of each agent as mild, moderate, high, or very high. All should be able to tell the difference between gas and the odor of powder fumes and screening smoke, and know whether the mask must be put on or whether it is safe to get along without it. Unfortunately, except for blister gases, there is no practical method for detecting gases other than the sense of smell. Noses vary. Some men are good smellers and some never can learn to distinguish. The latter are smell blind. In the Navy, color blindness is a bar to a commission. Smell blindness may be considered a serious handicap to the chemical warfare soldier.

Ability to identify chemical agents correctly is necessary in locating gassed areas, in applying first aid intelligently, and in quieting fears which arise from ignorance. For years all armies have tried to devise some kind of a chemical detector which would eliminate human factors and register automatically the presence and nature of all gases in the field.

All armies now have detector sets which are more or less effective for indicating the presence of the various war gases. They are used by special personnel. Our Army has a compact, simple and effective kit for use by chemical officers in the field. Most of our soldiers, however, must depend on the nose that knows.

A practical detector has been developed to indicate the presence of blister gases. This is a chemically treated paper or paint which changes color when touched by drops of blister gas. Gas detectors for individuals take the form of a pair of arm bands which are put on over the clothes of both arms. By changing color when the drops touch them, these detectors indicate to a man when he has been sprayed with blister gas. If he were wearing a gas mask he might otherwise not know of the contamination, especially if the droplets came down from a great height. A mark is made on each detector to indicate the size of the smallest drop which is likely to penetrate clothing. When the detector shows drops have fallen larger than this the man must take the necessary precautions, which include decontamination.

Ground gas detectors are pieces of stiff paper about two inches by four inches which come in pads of twenty-five designated as vesicant detector paper M6. Their purpose is to determine the extent of contamination on ground or material where gas is suspected or known. They are used on the end of a stick or bayonet by pressing on the suspected ground for about ten seconds. If the color changes to a reddish shade, blister gas is assumed to be present. These detectors change color with some of the liquid tear gases.

There is also available a detector paint (vesicant detector M5) issued as a part of the equipment of all types of vehicles. This paint is applied in the form of an eighteen-inch square to

a part of the vehicle clearly visible to the driver and his assistant. A band of this paint on the helmet may take the place of the detector arm band.

Pieces of detector paper in fixed frames may be placed around an area where the gas sentry can examine them occasionally and thus without taking off his respirator determine whether any spray has fallen on his area. A detector powder has also been developed, and vapor detector kit.

Recently our army has developed an ointment which is effective against the liquid blister gases. This ointment will be carried by all men as a part of their individual equipment. It has proved very effective in preventing blisters when applied soon after contamination with liquid mustard, and very materially lessens the effect of the gas when applied later.

The procedure in using the ointment is first to remove any gross contamination of mustard gas with cotton waste, cloth, or some other means. Then apply the ointment, rubbing it thoroughly into the skin for about a minute. Finally it should be removed with additional clean cotton waste or swabs.

In the case of lewisite which acts much more rapidly than mustard gas the ointment must be applied within a minute or two of contamination if blisters are to be prevented. Against liquid mustard gas, blisters may be prevented if the ointment is applied within five minutes of contamination. Blisters will be less serious if it is applied from five to fifteen minutes after contamination. The ointment will still have some preventive effect if used between fifteen minutes after contamination and the time when reddening of the skin begins. Once reddening has started the ointment should not be used as it may do more harm than good. The affected parts should be carefully washed, however, since the blister gas continues to dissolve in the skin until removed. The ointment

is effective for use after contamination with *liquid* blister gas. It is not used after exposure to the vapor.

The Germans have a somewhat different material called "Losantin." This is a stabilized bleach usually compressed into tablets. The tablets are crushed and applied with water to skin area contamination by vesicants. The Japs have a decontaminating powder.

Eye shields are used to protect against high-altitude airplane spray. Each British soldier carries in his gas mask haversack several eye shields made of transparent plastic material. When subject to air attack one of these shields is carried around the neck so that it can be quickly raised to the face covering the eyes. It is then held in place by an elastic band which fits around the head. The purpose of this shield, to which the British Army attaches great importance, is to protect the soldier's eyes from droplets of mustard gas while he is using his rifle to fire on hostile airplanes. This piece of equipment becomes of greater importance with the possibility of the use of nitrogen mustard which is so damaging to the eyes. Our men now have these eye shields.

And so the problem of individual protection involves:

First: What are we to protect against? The individual should be familiar with the various agents and should learn how to identify them quickly and surely, since his action will vary with the nature of the agent. *Second:* How will we obtain protection? For the individual the gas mask and protective clothing are the fundamentals for safety. He must have complete familiarity with this equipment and know how to care for it and use it. He must be able to wear it for long periods and work and fight in it without too great reduction of efficiency. Skill in its adjustment must be developed. He must have confidence in its ability to protect. With this confidence, the unreasoning fear of gas which the average man has should largely be eliminated.

There is a *third* factor in individual protection, however,

which is as important as any other, and that is development of gas discipline. The best equipment in the world will not be of any value unless the man puts it on when he should and keeps it on as long as there is any danger from gas. Proper training will develop gas discipline, but the perfection of discipline goes beyond training. It depends upon morale factors which are influenced largely by the attitude of the leader, who may be an army officer or an air-raid warden.

With satisfactory gas discipline and the equipment which is furnished, gas casualties can be reduced very considerably. Perhaps they can never be eliminated entirely, but I am satisfied that they need never be excessive. Since it is possible to reduce gas casualties by proper methods of protection, it is apparent that time invested in protective training in a community or an army will pay high dividends in keeping personnel available for working or fighting even though subjected to enemy gas. If every individual knows how to protect himself against gas and is skilled in the use of this equipment, effectiveness in a gas attack is greatly increased.

It is possible to learn much from our enemies. The instructions on defense against combat chemicals issued by the Military Chemical Department of the Italian Ministry of War contains one short paragraph which is worth quoting.

Individual protection, among all the means assigned, ought to be perfectly understood by all, down to the most humble private; and it ought to be an integral part of the general and ordinary training of the troops. The other means and methods of protection form the subject of special training for the commanders of the units, for the cadres of the various ranks and for the specialists (chemical troops and engineering troops). At any event, the various means and methods of chemical defense, if

they are to be really efficient, must all be based on a perfect discipline of the troops, on the spirit of initiative, and on the high and exemplary morale of the commanders of the various ranks.

XIV

PROTECTION OF GROUPS

THE training, discipline, and equipment of the individual is the keystone of the protective scheme. Individual protection is possible at all times so long as a man has a gas mask and protective clothes and is able to use them. There are, in addition, measures of technical protection that may be taken to safeguard groups of individuals from enemy chemical attack. These measures are grouped under the head of collective protection. They include the construction and use of gas-proof shelters; removal of chemical agents from ground, buildings, and material; protection of equipment, munitions, food, and water; use of gas alarms.

Many of the measures of collective protection are more or less complicated and consist in devices which are stationary or cumbersome. Collective protection should be considered as an auxiliary to individual protection. It is important and necessary in that it facilitates, frequently to a very great extent, the action of the individual and the group, but it cannot be substituted for individual protection, especially in the army. In cities it may be of prime importance, however.

During the First World War while conditions were stabilized for long periods, it was practicable to employ measures of group protection on a large scale. The type of warfare not only made elaborate collective measures possible,

but made them vital. During the early periods when gas clouds were released over wide fronts and the effect of a single gas attack was felt several miles behind the trenches, it was found necessary to install a complicated system of alarms to warn rear areas. Dugouts and shelters were gas-proofed and used extensively for the protection of reserves, medical aid stations, headquarters, and communication centers. Methods were worked out for clearing trenches and dugouts of the gases which, although non-persistent, would hang about in low places for a considerable time.

When mustard gas was introduced the need for gas-proof shelters became even more important on account of the persistency of the agent. Additional complications in removing the gas resulted because H is so persistent. The system of gas alarms needed modification since artillery shell became the principal means of projecting the chemical and hence many widely scattered attacks over small areas were the rule.

Toward the end of the war when mobility was restored it became increasingly difficult to use the methods of collective protection which had been designed for stabilized warfare. Today, however, most of these methods apply perfectly to the protection of our city populations.

One of the most difficult problems of collective protection is that of decontamination—that is, the removal of persistent vesicants of the mustard-gas type from ground or buildings. Suppose an enemy fires 10,000 shells, of which the greater part are mustard gas, over a mile or two-mile front. The ground where these shells fall is contaminated with a chemical which, under average conditions, will give up a vapor for several days. If breathed the vapor will affect the lungs and if it reaches the skin, will burn. Grass and under-

GAS CYLINDERS—CLOUD ATTACK
The first gas attack used the cylinder method.

SPRAYING MUSTARD GAS
(Mustard gas spray not easily visible as is smoke.)
This is the method by which chemicals now are most effectively used.

growth absorb the liquid. The best solution to the problem is to move out, and the sooner the move is made the better. However, higher command may decide that the ground must be held. It is necessary to assume that contaminated ground under certain conditions must be held. What then shall we do about it?

Every chemical agent can be destroyed by another chemical in the laboratory. In the field, however, the availability of the destroying chemical and the availability of personnel to use it, together with the extent of contamination, are the governing factors. If there are 10,000 contaminated spots in an area, it is impossible to destroy more than a small fraction of them unless the enemy agrees to an armistice while you decontaminate. It is possible, however, to take some protective measures which may help in cutting down casualties or in removing hazards which delay work. For example, it may be that one or two shells have fallen near the entrance to a message center or a command post which cannot be moved. There is always movement in and out of such places, and if blister gas is scattered about on the ground near the entrance to them, not only may the individuals walking over it be affected, but by bringing it into the shelters on their shoes or clothing, will contaminate others. In this case, measures may be taken to reduce the hazard from these few contaminated spots.

The best destructive agent for blister gas in the field is chloride of lime (bleach). Quantities of this material will be furnished for decontamination to units in the field and large stocks of it will be kept handy in cities, around industrial areas, and at airdromes. If the material is available, it can be used on the area near key points such as message centers or

command posts to eliminate or reduce the effect of the blister gas.

Briefly, the method of employing chloride of lime consists in applying to the contaminated soil a mixture of about one-third bleach and two-thirds dirt. This is spaded into the ground so that intimate contact is gained. Then another layer of the mixture is added and finally fresh earth is placed on top.

Although decontamination is possible, it is practical only on a small scale in the field. All that can be expected in the field is to take care of a few spots at highly important places. In cities, on the other hand, all areas must be decontaminated; the work must be done on the grand scale. Moreover, it will be practicable in cities. If decontamination is to be attempted on any scale, however, provision must be made for skilled personnel to handle the work. A separate decontamination organization will be necessary. Men engaged in the work must be provided with all of the regular protective equipment, and, in some cases, with impermeable clothing. Provision should be made for their undressing and bathing after they have completed their work. Arrangements will have to be made for the disposal of contaminated outer-clothing. Such squads are under the direction of unit gas officers or wardens.

Chloride of lime is effective in destroying Lewisite, as well as mustard gas. In the case of Lewisite, water will do much towards destroying the compound, since Lewisite combines with water very quickly. A solid product is formed by their reaction, so danger from vaporization is eliminated. The product (Lewisite oxide) is a very poisonous material, however, so after using water on the contaminated ground, it should be covered with fresh earth. As a matter of fact, earth, sand, ashes, or sawdust may all be spread over an area con-

taminated with H or L to give good temporary protection. This covering layer should be at least three inches thick. By hosing down with water, its effectiveness is increased.

There are other materials which may be used for destroying mustard. However, they are of no use unless you can get them. Civil defense officials in a city may be able to get sodium sulfite, which in a one per cent solution in hot water, is effective against mustard gas. Besides this, green solution (which is baking soda in sodium hypochlorite) is useful for destroying mustard gas on equipment and has the advantage of being less corrosive than bleach.

Buildings and shelters of various kinds may become contaminated with blister gas as a result of shelling or bombing with mustard- or Lewisite-filled projectiles, or as a result of the circulation through them of air containing the vaporized agent. Liquid mustard or vapor may be carried in from the outside on the shoes or clothing of persons entering. In the case of storage spaces, contamination may occur from leaky containers. In considering the problem of cleaning up such places, it is important to note the action of mustard on various materials used in construction.

Mustard penetrates wood rather rapidly, being soaked up more quickly by soft wood than hard wood. A wooden surface painted with ordinary paint will also absorb mustard. Wooden surfaces may be sprinkled with dry bleach or sprayed with a chloride of lime or hypochlorite solution. Wooden floors which have been heavily contaminated should be covered with a layer of bleach one quarter-inch thick, either dry or mixed into a paste with water, and kept covered for several hours, the layer being stirred or raked at frequent intervals. Finally the floor should be scrubbed with hot water, soap, and washing soda, and the room should be aired

for several hours and then inspected carefully for further signs of mustard gas. If heavily contaminated it may be advisable to burn the material so affected rather than to attempt demustardization. If this cannot be done for any reason, the treatment outlined above may be repeated as often as is necessary, until the mustard has been completely removed.

Certain paints and varnishes do not absorb mustard, and it appears likely that ordinary commercial paints will eventually be available which will prevent the absorption of mustard by wooden surfaces. Pure spar varnish is very resistant to blister gas. It must be remembered, however, that even a gas-proof paint will not prevent this agent from penetrating the cracks between planks or other breaks in the surface, unless these are calked and painted over.

Unpainted iron and steel work may have its surface splashed with liquid mustard. When the excess liquid has been removed a thin layer remains, which is extremely difficult to remove mechanically. It may be removed chemically by the same treatment as that prescribed for wood surfaces. Painted metal surfaces are susceptible to contamination unless a gas-proof paint has been used. A rusted metal surface is more difficult to clean than one which is not rusty. Repeated treatment with bleach or spraying with hypochlorite solution may be necessary before complete demustardization is effected. Machinery is usually coated with oil and grease, which readily absorbs mustard. The best remedy is to wipe off the surfaces with kerosene or gasoline, then swab with hypochlorite solution or chloride of lime (bleach) solution, taking care to remove all traces of the solution used, to prevent corrosion. The machinery should be again oiled or greased when clean. All rags used should be burned in a

blazing fire, personnel standing well to the windward to avoid mustard vapor.

Ordinary concrete surfaces quickly absorb mustard. Floors may be washed, hypochlorite or chloride of lime solution being used in preference to water. Dry bleach or a mixture of earth and bleach may also be used. After cleaning by any of the above methods, the concrete surface should be finally washed over with a solution of sodium silicate (water glass). This forms a smooth, non-porous coating which will prevent mustard from working to the surface and vaporizing. Concrete which has been previously treated with water-glass solution is more resistant to mustard, and more easily cleaned than untreated concrete.

Where equipment, contaminated with mustard gas, can be destroyed or thrown away, it is advisable to dispose of it in this way. However, if a field gun or other valuable equipment is splashed with mustard gas, it cannot be abandoned and must be cleaned so that the men using it will not be burned. If the contamination of the gun is heavy, it should first be cleaned off with kerosene or gasoline, being careful that the rags used are disposed of by burning or by burying deeply. Following this, a paste of chloride of lime and water will remove lingering traces.

A special non-corrosive dope has been devised by the Army Chemical Warfare Service for such purposes as this and will be furnished to artillery and armored force units and others who may meet with the problem of contaminated metal equipment. This is called decontaminating agent non-corrosive (DANC).

Several types of sprayers are supplied in the army for the application of decontaminating materials. These are commercial sprayers adapted for decontamination use. The smallest

is of the self-contained, hand-operated fire extinguisher type, and has a net capacity of 1½ quarts. It is carried as essential equipment in each truck, tank, and airplane, and is used for prompt decontamination of small but important items or surfaces with DANC.

A three-gallon pressure type apparatus is designed for spraying contaminated equipment with DANC. A strained suspension of chlorinated lime in the form of thin slurry may be used for the decontamination of building equipment not seriously affected by this material. The apparatus is a modified insecticide sprayer, equipped with an air pump and discharge hose with valve and nozzle. To operate, the top is closed and locked and the pump operated thirty to forty strokes. The apparatus is then slung upon the shoulder, the valve lever pressed, and the area sprayed. It is more useful for decontaminating matériel than terrain.

Both small decontaminating sprayers are widely distributed among troop organizations. A 400-gallon power-driven apparatus is assigned to special personnel and is designed for large scale operations, such as the decontamination of plane runways, buildings, tanks, or large vehicles. Mounted on a two and one-half ton truck, equipped with a power take-off, it is a modified insecticide sprayer with agitator and power-driven pump capable of delivering approximately thirty gallons a minute at 400 pounds per square inch. The decontamination of tanks and airplanes presents special problems.

Decontamination will generally be carried out by the units affected and all personnel and organizations in our army are trained to do this. However, Chemical Decontamination Companies especially trained for this work and equipped with the power driven apparatus are available for large scale operations.

Although decontamination frequently will not be practic-

able for military forces in the field except on a very small scale, it will be important on an airdrome, in a city and around an industrial area. In such cases, however, labor, equipment, and material will all be available, and the decontamination operation not only necessary but practicable.

Just as the gas mask is the basic item of equipment for individual protection, the gas-proof shelter is the basic requirement for protection of groups. Where an organization is subjected to chemicals for long periods (say two or three days) and unable to leave the contaminated area, provision must be made for relief of men at frequent intervals or places must be provided where they may go to rest, eat, and sleep without wearing gas masks.

Certain work has to be carried on without the encumbrance of the mask. This requires that such places as medical dressing stations, message centers, and headquarters be located in houses, shelters, or dugouts into which gas cannot enter. The need for gas-proof shelters is apparent. The extent to which gas-proofing can be carried out, however, depends upon the situation.

In a war of movement, gas-proofing must be of an improvised type, possible only when the situation stabilizes for a period of two or three days. Higher headquarters generally are fixed for periods sufficiently long to warrant provision for fairly complete collective protection.

In stabilized conditions where both sides are dug in and there is no prospect of a change for a matter of several days or weeks, gas-proofing is necessary on a large scale, and will be possible from the very nature of the situation.

Experience in the First World War was largely that of a stabilized situation and protective shelters were highly im-

portant. They were usually dugouts which in some cases were little more than splinter-proof and in other cases were twenty feet or more underground and bomb-proof. When operations reached the stage where the trenches were left behind and warfare became mobile, the need for gas-proof shelters remained, but the opportunity for constructing them was lacking. Command posts of battalions and in many cases regiments moved very rapidly. Those of brigades moved less rapidly and the command post of a division usually did not move oftener than once in two or three days. It was impossible to foresee the progress of the battle, however, and the probability of movement was great enough to prevent the construction of any but the simplest gas-proof shelters. Had it been feasible effectively to gas-proof the shelters quickly, it would have been done.

Regardless of whether or not conditions are mobile or stabilized, there is no question that gas-proofing will be required whenever it is possible in a war of chemicals. Provision will have to be made for field hospitals and certain command posts. Gas-proofing often will consist in modifications of one room in a house or a cellar by sealing up the cracks and constructing an air-lock. It will be necessary in many cases to provide some means of introducing purified air into the protected space.

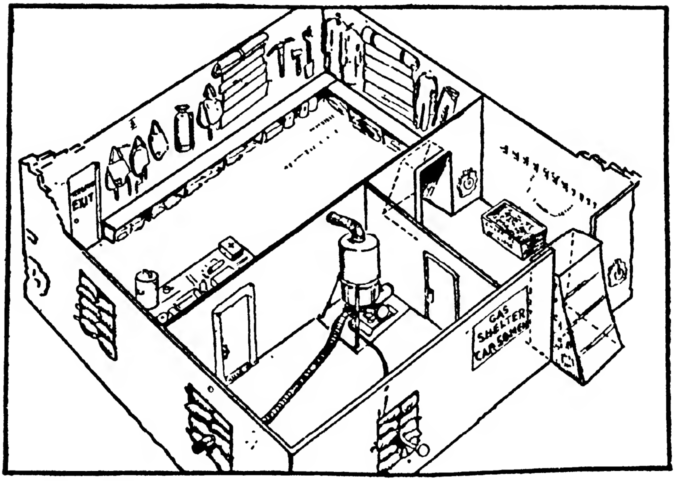
The principle involved in the gas-proofing of enclosed spaces is the elimination of drafts. This is accomplished by closing ventilators and chimneys, sealing all openings and providing an air-lock entrance. The latter prevents the rush of air into the shelter when the entrance is opened. The air-lock is merely a system of two doors with sufficient space between so that only one door may be opened at a time. In permanent construction gas-tight doors of wood or steel

would be used. For dugouts or temporary shelters two blankets hung on slanting door frames and about eight feet apart will serve. The diagram on page 222 illustrates the method of constructing an air-lock entrance for a dugout or surface shelter.

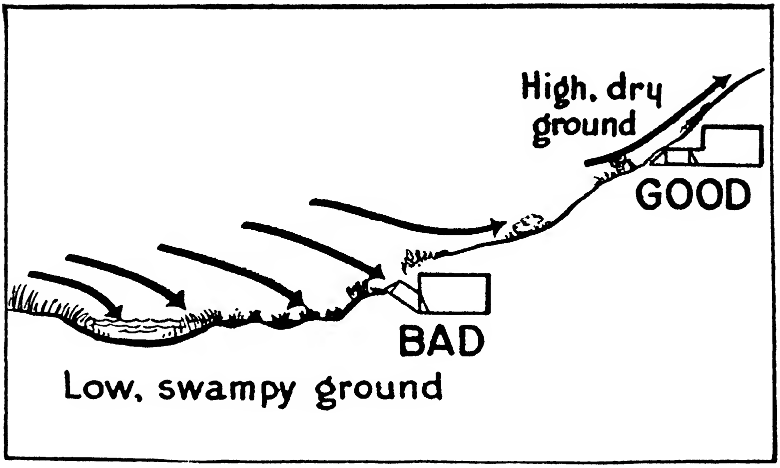
There should be no misconception as to the nature of temporary gas-proof construction. There is no air-tight cell required. In most cases there is a chance that small quantities of the gas may leak into the shelter. Every effort should be made to seal cracks and openings around windows and doors, between floorboards, around radiator and water pipes but the principal requirement is to prevent any rush of air from outside to the interior when the door is opened. The blankets in the blanket door construction are not air-tight closures; they are merely practical affairs that prevent drafts from outside. As a matter of fact, they serve very well if they are kept moist. In the case of mustard gas it may perhaps help some if they are impregnated in the same manner that clothing is impregnated. This is not essential, however.

If the blankets are dry they will not present as good a barrier to gas as they will if they are wet. I do not believe, however, that it will be practicable in many cases to have them moistened with neutralizing chemicals, nor do I believe that it is vital. The main thing is to have them lie flat against the door frames and not be too porous. Moistening with water will accomplish this sufficiently well. Ordinary blankets if kept mended and moistened will be adequate.

Improvised shelters of temporary construction will be all that is possible for most installations, for homes, and small bomb-proofs. These will be non-ventilated shelters—that is, no means will be provided for changing the air. In such places fires must be put out when they are closed. Fires use



COLLECTIVE PROTECTOR



GOOD AND BAD SITES FOR DUGOUTS

up oxygen quickly. Wherever possible, however, and it will have to be possible for important installations, ventilation will be provided. This will be accomplished by means of a collective protector. This is a machine which forces air by hand- or motor-driven blower through a filter resembling a large gas-mask canister.

Portable collective protectors are used so that gas-proof shelters for certain headquarters, dressing stations, and communications centers can operate when subject to concentrations of gas for periods over twenty-four hours. A large collective protector has been designed and standardized for large permanent installations, such as coast defenses.

The collective protector consists in a filter blower unit constructed by the Chemical Warfare Service which furnishes filtered air to enclosed spaces such as the plotting rooms of coast defenses, the plotting rooms and central station of a battleship, and important rooms for permanent higher headquarters, or important places in cities. The installation of the unit and the design of the room to effect airtightness are tasks of the Engineer Corps.

If possible, gas-proof shelters should be placed where they are least likely to be affected by gas. For example, if there is a choice, select for gas-proofing a shelter protected from the wind, as on the lee side of a hill, and avoid using a shelter in a depression where gas would tend to collect. It is possible in general to decide what places are most likely to be gas traps and what parts are least likely to retain gas concentrations. Balancing these factors against the normal requirements for cover will give the best answer to the question of location.

The removal of gas from enclosed spaces will present a problem. If, through some failure of the protective scheme, a dugout becomes filled with non-persistent gas, the best

method of removing the contaminated air is to open all outlets and build a fire of dry wood. This will cause rapid ventilation. In a building, opening all doors and windows will probably be sufficient to remove non-persistent gas. If liquid mustard or any persistent agent has been splashed on the inside the process of removing it is a very slow one. I do not know how you would go about making a dugout contaminated with liquid mustard inhabitable in a few days. If the contamination is great, the best thing to do is to abandon the dugout permanently; decontamination would be a long and laborious process.

The protection of material, food, and water is best accomplished by keeping them away from the gas. Small instruments and weapons may be stored in gas-tight chests. In the case of larger pieces of equipment, tarpaulins or protective covers may be used to keep off liquid mustard sprayed from planes. Special containers will have to be used for foods. Cellophane is an excellent protection against mustard. Cellophane-wrapped foods in individual packages, and small cuts of meat frozen by the "quick-freezing" process and wrapped in cellophane may be one answer to the food problem before the present war is ended. Canned foods, of course, offer no great problem except contamination from handling cans the outside of which have been splashed with vesicants. Modern war conditions require that either the ration itself be issued in gas-proof containers or the ration cart be made gas-proof.

No specialized technical knowledge is required for the protection of material or food. In all cases, the action required is the common-sense one. The application of good judgment will generally dictate what measures should be taken to protect food or material.

During the First World War a complicated system of alarms grew up on account of the danger from gas clouds. When artillery shell became the principal means of discharging chemicals, the old general alarm systems were still retained. Artillery gas shoots, however, are largely local in nature; consequently many men were needlessly put in gas masks when a few shells were fired over. This is something that must be avoided in the future.

Normal means of communication, which have been so greatly perfected since the First World War, will serve to give warning of large-scale gas attacks and pass the word back to the rear as far as necessary. Special alarm devices are not needed for local gas-shell attacks. Men must be taught to recognize gas and to put their masks on as soon as gas is detected. The man first detecting gas should warn those around him. If the men in a squad do not put on the mask when they should, the corporal or senior member should order them to do so; similarly, the sergeant should be responsible for the masking of his section, and the lieutenant for his platoon. To warn working parties or sleeping men, some improvised device is all that is necessary. An empty shellcase with an iron bar, a piece of railroad iron and a hammer, or some other device which gives a distinctive sound will serve very well. Great care should be taken with regard to passing on gas alarms because putting men into gas masks needlessly will result in a breakdown of gas discipline and will reduce the efficiency of the command.

In cities it will be necessary for air-raid wardens or some agency of the Civil Defense to make sure that alarms are given when gas is used. Each small district should have its distinctive gas alarm and the warden must enforce masking and taking all anti-gas measures.

The responsibility for the protection of any military unit against gas is that of the commanding officer. He is responsible for the protective training of the personnel, the supply of protective equipment, the taking of all protective measures, and the maintenance of gas discipline. The special duties connected with protection, however, are so great that it is necessary for a commander to have a staff officer to assist him in this work. The headquarters of each field army, corps, and division includes a chemical staff section, composed of personnel of the Chemical Warfare Service. The duties of these sections cover chemical warfare in general, and protection is only one of the phases.

Below the division, each brigade, regiment, battalion, or equivalent unit is required to designate a qualified officer and a non-commissioned officer from its own personnel to perform the anti-gas duties. Each company designates two gas non-commissioned officers. Since chemical attack on rear areas by aircraft is possible, and in fact probable, a protective organization must be provided for all installations.

The duties of unit gas officers and gas non-commissioned officers are essentially protective. In peacetime, or when chemicals are not in use, their work is in addition to their other duties. In a chemical war, however, it will be necessary to relieve them from all duties except gas protective duties. It is the unit gas officer and his non-commissioned assistants who will carry the tremendous burden of assuring that all necessary measures for protection against gas are taken.

This anti-gas personnel acts for the commander in assuring that each individual is properly trained in the use of anti-gas equipment and in the action that should be taken before, during, and after a gas attack. They are concerned with supply to the extent of satisfying the commander that the

unit is properly equipped. They will assure that the necessary measures for collective protection are taken. Their importance to the protection of the command increases during the march and during battle. The company gas non-commissioned officer is an important cog in the machine. He assists the company officers in the inspection and fitting of gas masks and in instruction. He should be well qualified in the identification of chemical warfare agents and able to make minor repairs to gas masks.

All sentries will act as gas sentries, but special gas sentries should be posted in the vicinity of the gas alarm and wherever any number of men are sleeping or working. Gas sentries must be detailed wherever there are any quantities of supplies, to see that these are covered and protected against gas in the event of attack by airplane.

A great many of the measures to be taken for protection against gas are routine. All of these routine measures should be gathered into what is called a standing order. Standing orders are generally published by the commander before a division enters the theatre of operations. Their observance is an excellent indication of the state of the gas discipline of any command. The importance of gas discipline cannot be emphasized too much. It can be developed only by training and leadership.

It is apparent that protection against gas complicates things very much for the fighting man and for the worker in industry. There is no doubt that the introduction of chemicals has complicated war. Proper training and discipline, however, provide the solution to the problem. More work is involved, but if this work is faithfully carried out, gas casualties may be reduced, the soldier will fight effectively, and the civilian will keep the wheels of industry turning.

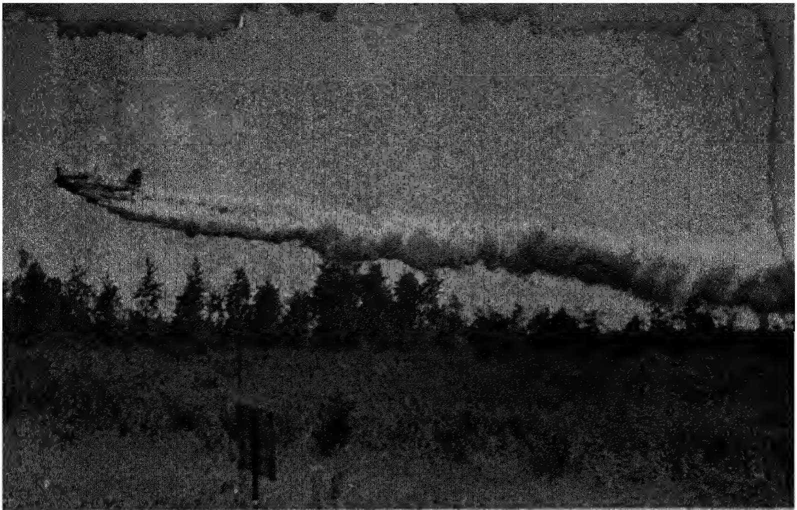
XV

TACTICAL PROTECTION

EVERYONE is agreed that the soldier of today must have adequate protective equipment to withstand a gas attack. This, however, is not enough. The problem of protection against chemical agents goes beyond the mere matter of equipment and the training in its use; it involves action on the battlefield or in the presence of the enemy, which requires much thought, careful organization, and intelligent training.

Napoleon maintained that every plan of campaign must be based on a sound plan and well-thought-out scheme for security. He said, "I endeavor to conjure up all possible dangers, to foresee all difficulties. Military service consists in weighing carefully all possible eventualities and then eliminating, almost mathematically, chance."

It is of course impossible to eliminate chance entirely in plans of protection against enemy gas, but it is possible to "foresee the difficulties," and make all possible provision for them. Unless commanders and civilian authorities do foresee the difficulties that gas, especially persistent gas, may create, and take steps to counteract or circumvent these dangers, armies and industry will be delayed in their activities, excessive casualties will be caused, and attacks and production will bog down from confusion and disorganization. From what



ATTACK PLANE LAYING SMOKE
(Blister gas could be used from same tanks.)

SMOKE SCREEN OVER WATER

we know of developments in chemical warfare, this is not far-fetched speculation. It is a fair estimate of what probably will happen to the command or the industrial center or air-raids precaution service unprepared to meet enemy gas.

Suppose an army is preparing for an offensive. Large bodies of men are being brought up to assembly areas. Consider the effect of covering large portions of these areas and the roads leading to and from them with mustard gas or Lewisite disseminated by bombs and spray from airplanes and by artillery and mortar shell. Unless careful plans are made, anticipating the action to be taken in such a case (even though the protective equipment is complete and the best possible), the freedom of action of the army may be lost and the enemy will have accomplished what he set out to do.

Wherever gas is used it will affect every individual and all action.

The infantry commander planning his approach march must allow for delays that may be encountered by the presence of areas of persistent gas along his route. The company officer will have to count on difficulties in getting his ration carts safely through zones contaminated with mustard gas and Lewisite. The engineer charged with repairing bridges and roads will find it necessary to count on the combined effect of mustard gas and high explosive. The signal officer, planning his communications net, must take into consideration the possible effect of mustardized areas in the ravines and valleys where he plans to lay his wire.

These are a few of the problems that must be solved in a war involving the use of chemicals. They must be solved in the field by every arm and service. A knowledge of tactical protection against gas is as important as a knowledge of the use of the gas mask. To the commander charged with the

great responsibility of conserving his forces and bringing his command to battle intact and able to fight, it is more important.

Any discussion of protective measures should be based on what an enemy desires to accomplish by his use of chemicals. According to the British teachings in their *Tactical Notes On Defense Against Gas*, published by the War Office, there are three main objectives for chemical attack—to inflict casualties, to harass and thus lower morale, and as a means of delay, either alone or in combination with demolition.

The Russians have a similar but somewhat broader conception. Their text, *Military Chemistry* by Fishman, lists the following objectives: To inflict mass losses on the enemy; to hamper the fire and maneuver of the enemy; to break up the normal work of the rear; and to destroy morale.

The principal gas weapons that were used during the World War—the cylinder, projector, mortar, and artillery shell—must be counted on in the future. We can take these weapons for granted, making due allowance for probable improvements in technique. It is the new methods to which we must now give the most thought in a study of protection, for tremendous progress has been made in the dissemination of chemicals. During the First World War the airplane was never used for projecting chemicals. Today the military world recognizes the potentiality of air chemical attack and has made preparations to use it offensively and meet it defensively.

In introducing chemical defense the text of the Red Army lays out six tasks to be attained, of which four are concerned with tactical protection. These are—to discover the enemy's intention; to select positions with reference to chemical defense; to prevent enemy chemical attack by an active

defense employing artillery fire; to notify troops of chemical danger; to use protective equipment; and to carry out degassing. The Russians state that these tasks demand the most careful training, and a high degree of "physical fortitude." They comment particularly on the effect of gas on morale—a feature that is important yet strangely neglected by most discussions.

In our own teachings tactical protection against gas includes chemical warfare intelligence; chemical warfare reconnaissance; selection of routes of march, camp sites, and battle positions; the protective disposition of troops to avoid enemy gas; and offensive action to forestall or disrupt enemy chemical operations.

It almost goes without saying that the security of an army depends to a large extent on information. A careful intelligence scheme is demanded in order that the information may be timely, complete, and accurate. So far as chemical warfare is concerned, it is of such a technical nature that special knowledge and training are required in the interpretation of chemical intelligence data.

An example of chemical warfare intelligence is cited from my own experience: As the gas officer of a division occupying a rather quiet trench sector in the Haute Alsace in 1918, I received a report from an especially keen and capable regimental gas officer that noises in the German lines indicated that trenches were being dug and metal drums or tanks installed. This suggested to the gas officer that the Germans might be emplacing gas projectors. The position from which the noise came, however, was more than two kilometers from the nearest probable projector target in our lines; up to that time it was believed that the maximum range of projectors was only about 1600 meters. Just prior to this,

I had received word from the gas officer of the French corps with which our troops were operating, that the Germans had developed a rifled gas projector of longer range—about 2800 meters, which recently had been fired against French troops on our extreme right. In view of this report the noise of the digging came from a position that would permit firing into a logical target in our lines if the new weapon were to be used. Upon request to the division intelligence section, aviators took a photograph of the place indicated, which showed a new working that looked like a projector emplacement. The regiment was warned and shortly thereafter the projector attack from that emplacement was made. Protective preparations reduced casualties to less than twenty, although a tremendous concentration of gas fell in a small area in which some 250 troops were located.

The fact that our artillery did not blow up the enemy's installation before it could be fired will be remarked, but there were reasons which prevented this in spite of recommendations that it should be done. The point is that chemical warfare intelligence data had been secured and that it resulted in preventing a large number of losses.

In addition to combat intelligence, there is command or War Department intelligence for which also a technical knowledge of chemical warfare is required. An outstanding example of chemical warfare intelligence, as it applies to this form, is the already mentioned accomplishment of the British Intelligence Service in learning in advance of the contemplated use by the Germans of phosgene gas. British agents learned in the summer of 1915 that a new gas—phosgene—was being made by the Germans. The formula was obtained, as was the time and place it would be used. The British and their Allies were thus able to devise a gas mask that gave

protection against the new agent, and were prepared for the attack when it came.

Such an achievement is, of course, rare, and it is rather with the everyday factors in chemical combat intelligence that the average officer is concerned in his effort to assure chemical security. Such factors are the weather, terrain, activity and armament of the enemy, state of enemy gas discipline, training and protective equipment, location and extent of contaminated areas and the interpretation of enemy chemical tactics. As an example of the last factor, an estimate may be made of the enemy's intention from his use of persistent gas. He is not likely to place it where he intends to attack. General Foulkes makes this very clear in his book *Gas!* in discussing the use of mustard gas by the Germans in the spring offensive of 1918. He says of the attack on March 21: "The exact front of the German assault was known accurately, as it was actually marked out for us by the enemy on the map by the preliminary use of mustard gas."

There is much information to be obtained from every gas attack and an accurate report is required of the gas officer. This officer should keep a gas situation map on which are plotted all gas attacks within his area. This is necessary especially where persistent gas has been fired.

A chemical laboratory company is now provided where large numbers of our troops operate. The laboratory company is an important link in our chemical intelligence system. One of its duties is the analysis of enemy chemical materiel.

Reconnaissance is one of the principal factors in chemical security. All reconnaissance activities are carried out with careful reference to chemical warfare considerations. In ac-

tive operations, chemical reconnaissance is the principal responsibility of the unit gas officer for brigades and lower units; for divisions it is an important duty of the protective section of the chemical officer's staff. In the future, even in rear areas, commanders must keep in mind the possibility of persistent gas along their routes of march. In gas warfare only by careful reconnaissance can there be assurance that a command is not running into areas which have been contaminated with blister gas.

This type of reconnaissance is carried out by personnel trained in chemical warfare. It involves a knowledge of the possible uses of chemicals by the enemy, the behavior of chemicals on various types of ground, and the effect of weather on chemicals. Probable danger areas are first identified on the map. Then personal reconnaissance determines the actual danger areas.

In the Italian Army special patrols for chemical defense are provided. Their duties are described in detail in the training regulations issued by the Military Chemical Department of the Ministry of War in Rome. Every company has a patrol consisting of a corporal and three men for chemical reconnaissance. Each battalion has a similar reconnaissance patrol. Company and battalion patrols frequently operate together under the orders of the chemical defense officer of the battalion. The special duties of these patrols are to keep track of weather conditions and the probability of chemical attack; to guard against surprise; to conduct chemical observation; and to cover the company chemically in the most dangerous direction. German and Russian instructions resemble the Italian.

When on the march or when moving into new positions gas officers of each unit, with such staff as they have, should

march with the advance party. Someone skilled in the identification of agents and able to recognize gas immediately should be up in the most advanced position—the point. Trained observers are also necessary on the flanks, especially on the upwind side.

If persistent gas is located, or if warning is received that there is a gassed area along the route, the unit gas officer should determine the extent of the area and recommend whether to go around it or through it. If the area must be traversed, he should take such steps to minimize the gas danger as are practicable.

In the selection of resting points, bivouac areas, and battle positions, contaminated places or gas traps must be avoided. When a gassed area is located, careful reconnaissance should determine its extent, the kind of gas, whether concentration is strong or weak, and the best way of getting around or through it. If a good route that skirts the upwind edge of the gassed locality be available the command can proceed without difficulty or much loss of time. If there be no good upwind passage, but a good route downwind exists, the troops can get past safely by wearing the gas masks. Many times, however, no way around the area will be practicable and the command must march through as quickly as possible. The job of the reconnaissance party is to determine what action is best. It may be desirable for degassing squads to prepare a passage, although this is not easy and can only be accomplished properly by trained personnel and much equipment.

Given anti-gas squads properly equipped and trained, the burden of chemical reconnaissance will not be excessive, but the gas danger can be reduced only by careful planning, organization, training, and the maintenance of gas discipline.

The most significant change that chemicals have introduced into modern battle is that caused by the effect of areas of persistent gas on movement. Since freedom of maneuver is essential to successful military action—whether offensive or defensive—anything that interferes with this freedom must be combatted. Persistent chemical agents have introduced a new factor in warfare which puts an additional premium on careful preparation and skillful maneuver.

K. Litvinov, as early as 1933, stated in the Russian journal, *War and Revolution:*

Modern attack without first overcoming the gas obstacles of various types and character is impossible. Only a coincidence of entirely exceptional circumstances may prevent the enemy from employment of this effective arm in order to strengthen his defense. The present development of the technique of terrain poisoning enables one so effectively to poison extensive stretches of the country that they can be crossed only with the greatest difficulty.

Litvinov suggested several technical means of protection. Men must be equipped with gas-proof boots and capes. In some cases chloride of lime may be scattered on the ground to neutralize the mustard gas or lewisite. This is accomplished with the aid of mechanical devices. Where practicable, the ground may be burned over, and there is also a suggestion that tractor-driven scrapers may be employed for removing the surface of the ground. Such means are considered practicable, although their difficulty is recognized by the Russian writer. Mechanization has increased possibilities.

Litvinov favors a method which is also mentioned by the British in their *Tactical Notes on Defense against Gas*—the laying down of protective capes. The combat echelons cross the contaminated area under cover of smoke, wearing gas-proof footgear and carrying capes or similar devices for

covering the ground. They advance by rushes in small groups. The capes are thrown on the ground and left there, one cape serving several men. Other men come forward with fresh capes, and as the advance progresses, the capes form small islands of protection against the contaminated surface. It is understood that the Japanese plan to use rolls of grass matting in a somewhat similar manner. Gas obstacles will generally be covered by fire in order to keep the attack close to the ground, and hence in contact with the chemicals. Some means must therefore be devised to keep the soldier's body from contamination when heavy concentrations are on the ground. Such concentrations, however, are likely to be rare. Ordinarily by using care, masking, and moving through the contaminated area rapidly, casualties will be few.

In any defensive action wide use of mustard obstacles is to be expected and they will be used to an even greater extent in a retreat. Obviously, such gas obstacles do not physically bar passage since the effects of the vesicant, unless the individual be grossly contaminated, will not show up until several hours after exposure. Consequently, the soldier, aside from some loss in morale, may be able to fight for six or eight hours or even longer. Troops can get across infected terrain and will get across it if the mission requires it. It was one of Napoleon's war maxims that "an army can pass always and in every season wherever there is room for soldier's two feet." However, the commander who is faced with a gas obstacle must consider what is going to happen to his men in passing through. The situation may not justify risking casualties.

Efficient protective clothing will be an important factor in reducing casualties. Nevertheless, the presence of blister gas on ground will cause a command to mask and this masking in itself will retard movement. The time factor is

definitely affected whether troops are on the march or engaged in an attack.

Everywhere a persistent gas is used it hampers operations and causes loss of time. The commander, in making his calculations, must take this into account. The protective means at his disposal are protective equipment and the tactical means of reconnaissance, information, and planning. If properly used, the unit gas officer should play a big part in the protection of his command.

A subject that was given very little attention during the First World War, but one of paramount importance, is what may be called planning for protection. This involves the making of plans in advance for the movement of troops to alternate positions in case of gas attacks.

Many gas casualties could have been avoided during the First World War had adequate schemes been outlined in advance for the movement of troops to alternate positions in the case of mustard-gas attacks. In offensive situations, plans are necessary to determine the action to be taken upon meeting gassed areas. On the defensive, there should be a plan as to what each unit will do if it encounters mustard-type agents. This is especially important where the position is to be occupied for twelve hours or longer.

This plan need not be elaborately worked out on paper in the case of smaller units; it may consist merely of the selection of a suitable alternative position to be taken. This, however, should have the approval of the next higher unit, in order to avoid conflicting with near-by organizations. For battalions and higher units, the plan should be written and carefully coordinated with near-by units.

The selecting of alternate positions must be so made that

there will be no serious gap in the line and the units may continue to assert their fire power.

I can recall an instance in my own division during the former war where unnecessary gas casualties resulted because authority had not been obtained and plans had not been made in advance for the movement to alternate positions. Men were compelled to remain on mustardized terrain, when they could have been withdrawn and the ground held by a few machine guns on each flank. After this particularly severe lesson, permission was granted to withdraw troops from contaminated positions or to relieve them frequently. A striking opportunity for comparison occurred when gas attacks under almost identical conditions were made upon two companies of the same battalion within a period of about eighteen hours. In the first attack the company was not moved out of position for fourteen hours. This resulted in 256 casualties out of 300 men exposed. The second attack, with 250 men exposed, resulted in only seven casualties going to the field hospital and about 50 being treated for slight eye burns. Here the troops were withdrawn as soon as the nature of the attack was recognized, and guards were posted to keep men out of the gassed area. The same type of ground, the same area contaminated, approximately the same number and kind of gas shells, and same type of troops—yet one body of men suffered heavily while the other got off lightly.

Knowledge is power in gas defense. It saves casualties, increases the confidence of men in their own ability to protect themselves, and reduces fear. The more knowledge we have of gas, the less gas can tie us down and hinder freedom of action.

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XVI

PROTECTION AGAINST AIR CHEMICAL ATTACK AND CIVIL PROTECTION

IN the new World War it is necessary to provide for protection against enemy chemicals everywhere that their airplanes can fly. Gas used to concern only the soldier. Now it concerns everyone. Of all methods of chemical attack, the discharge of chemicals from airplanes raises the most serious problem in protection, and it is especially difficult to protect against the airplane spray. The range of air chemical attack depends upon the cruising radius of the airplane. This is being increased every year. On the basis of present military aircraft we can make an estimate of the zones in which enemy aircraft might operate in war today, but tomorrow we shall most certainly have to extend these zones.

We must count on a cruising radius of long-distance bombers in the neighborhood of 2500 miles in the not too distant future; that is, 2500 miles out from airdrome and 2500 miles back, without a stop. There is theoretically, a safety zone 2500 miles from the nearest enemy base but the safety depends not only upon front-line troops holding, but also on the accuracy of our estimate of the enemy's cruising radius. Official data for the distance that military planes can span should never be depended upon as a basis for plans of protection. Moreover, we must consider the psychology of

an enemy who may reckon a certain distant objective of vital importance and whose conception of duty and patriotism may be such that he will think only of the distance to the target and not of the return flight. Consequently, protection against gas in what might be thought a safety zone should approximate that needed within bombing aviation range.

The first line of defense against the bombers is our own air forces. The next is anti-aircraft artillery and barrage balloons. The third is the passive defense of bomb-proofing, camouflage, large-area smoke screens, dispersion, and air-raids precautions. No matter how effective the defense, some of the attack will get through. There is no such thing as an impregnable defense against air attack. Plans must be based on breaches that will occur.

Combined explosive, incendiary, and chemical attack will be customary in a chemical war. The explosive and incendiary will destroy, while the chemical will search out individuals behind barricades, and cause delay in repairs.

Troops at the front have the most difficult problem in any scheme of protection against gas. Here it is necessary to guard not only against gas attacks from bombers and artillery firing chemical shell, but also chemical spray spread by fast, low-flying attack airplanes. The last is the greatest danger. Every grove of trees or wooded hill mass presents a mask from behind which an airplane flying at 300 miles an hour and at an altitude of 150 feet may come to fire assorted weapons upon ground troops. When these planes approach, the man on the ground does not know whether he will be hit by machine guns and fragmentation bombs, or machine guns and chemical spray, or all three. It may indeed be a combination of all.

Anti-aircraft defense has been developed with attack by explosive and machine-gun bullet in mind. Nearly all the thought on this subject has been devoted to attack with these weapons. Not enough thought has been given to defense against chemical spray, or combined explosive and gas attack behind a smoke screen. Yet spray is a greater menace to ground troops than bombs and bullets. It offers more chance to the attacker of a successful return for the effort he has expended.

Fire from rifles and machine guns is the reply of ground troops to low-flying air attack. When attacking with fragmentation bombs or machine-gun fire, the airplane must fly directly over the ground troops, but in the case of chemical spray, the aviator does not have to fly directly over the target. He can fly upwind of the target, sheltered perhaps by partly wooded areas, and by following a course at right angles to the wind, drift his spray over the ground troops without being seen. True, he must know their location but he has a wide margin to work with; for he can cover a band about a mile in length and a quarter of a mile wide.

It is no more difficult or dangerous to spray gas than it is to drop bombs. If a protecting smoke screen precedes the actual attack, it will be difficult if not impossible to prevent a flyer from laying his chemical and getting away safely.

If the attack unit is not willing to risk ground fire, chemical planes can safely place bands of persistent blister gas along the routes that ground troops must follow, a few minutes or a few hours before troops reach the areas. Defiles and valley roads will be excellent targets. Don't forget that mustard remains effective on the ground for hours and even days. The mission of such air attack is to hinder, to delay, to impede. Casualties are secondary—the plane's mission may

be accomplished if it can cause a column to take a longer way or enforce delay by masking.

Against air chemical attack we have *what?*

For the soldier we have a gas mask and protective ointment, protective clothing that protects the body from vesicant vapor, and protective covers to shed the liquid; we have movement and ground fire and normal security measures, which include information, dispersion, and air patrols. For the civilian we have gas masks, protective shelters, air-raid precautions services, and the aircraft warning system.

At the first warning a soldier must adjust his protective equipment and then open fire on the plane if he can. The speed of the plane, which will not be less than 300 miles per hour, will give a soldier little time to adjust gas protection and deliver effective fire. Air attack can be launched and completed in less than thirty seconds. Troops will have less than ten seconds to fire at planes within effective range. The adjustment of gas protection will take six or eight seconds at the least. If there are any seconds remaining, the soldier should counter the attack with every available weapon.

There is some argument as to what a soldier should do about enemy low-level air attack. Should he shoot first or put on his gas mask? He can't do both. If he shoots and the plane is spraying chemicals he is a certain casualty, head up sighting along a rifle barrel; the burning spray can't miss unmasked face and eyes. If he stops to put on his mask or don his protective cover it will be too late to shoot. What would you do? The possibility of air chemical attack gives us an excellent reason for the development of speed and skill in putting on the protective equipment.

Consideration must be given to the drive against the soldier's morale by this destructive machine from the air

with its sudden dash at full throttle, dropping bombs and spraying machine-gun bullets and gas. It is more terrifying than the Stuka and I believe more effective. It was shown mathematically a few years ago that three planes at that time could fire only 5,400 bullets over an area of 2,200,000 square feet with ineffective plunging fire—but is the soldier a mathematician? Moreover, chemical spray fills the air with innumerable minute gas bullets, and after one good gas attack it will not comfort the soldier to know that in the next one his share of the air will be affected by only a few thousand poisonous particles. We shall have to give him something better than mathematics. It will take careful training, a high degree of gas discipline, and absolute confidence in his protective equipment to insure steadiness under such a threat.

Where air attack is possible, anti-aircraft detachments completely equipped for gas protection should be in constant readiness to open fire immediately on enemy planes. Half of the men in each detachment should have the mask adjusted and all should wear impervious gas-proof clothes to shed mustard or Lewisite spray. Since marching in impervious clothes is impossible except for impractically short distances, anti-aircraft machine-gun detachments should be carried on light, cross-country vehicles, and should be scattered through marching columns at proper intervals.

When large bodies are on the march, anti-aircraft artillery should be provided to go well ahead of the troops to guard especially dangerous portions of the route, such as defiles or mountain passes.

Tank units have more to fear from chemicals than from bombs or bullets since the molecules of gas can penetrate armor that will shed heavy caliber anti-tank munitions. Chemicals provide an effective solution to mass attacks of

armored forces. I should not want to be in a tank sprayed with one of the blister gases.

Night operations offer the best protection against air attacks with explosives. It is possible that since it is more difficult in the dark to hit a target with bombs or bullets, the use of chemical spray may be favored for night attack.

Dispersing on both sides of the road is a rule against air attack, but it is of little use against chemical spray. The first action should be to get on the gas mask and adjust protective clothes. After a chemical air attack the command should move upwind as soon as possible to get out of the contaminated area. Then first aid and degassing should be started.

It is an interesting and important fact, to be emphasized, that wooded areas, which offer excellent protection against explosives, not only afford no protection against gas, but are, in fact, danger spots. Heretofore, the soldier has sought the woods for cover. He must remember that he is not safe there from gas.

The need for gas protection complicates matters greatly for the fighting man. We can do something about gas, however, and casualties from that source can be reduced. The perfect solution to the protection problem has not yet been found, but the Chemical Warfare Service of our Army has developed the finest equipment possessed by any army in the world today, and has laid out training methods that when followed will guarantee reasonable security.

Protection of Civil Population

In the many writings upon the dangers to civil populations from gas, there have been two views presented; and each one is an extreme. Some imaginative writers have asserted that

large bombing planes carrying chemical agents may drench cities and towns with gas and literally blot out entire populations. Others have replied that chemicals will not be used against cities and towns because of ineffectiveness. With figures as to the amount of gas a plane can carry and the amount required per square mile of terrain, the latter have maintained that it would be impossible to put enough gas down on a city to do serious harm, and that high explosive bombs would be so much more effective that they would be used exclusively.

Both views cannot be correct. In fact, both are absurd. It is important from the standpoint of safety to our people in congested areas to know the probabilities. The truth lies in the middle ground. Gas is a valuable weapon against industrial and political centers just as it is a valuable weapon in orthodox warfare and to the same extent. Against industrial targets it will exert its tremendous moral, disorganizing, and casualty effect. In a gas war the chemical weapon will find wide use as an important auxiliary to high explosive. It will not wipe out populations, nor will it entirely supplant explosives; but it will be a most effective weapon.

If this is true, it follows that provision must be made for the protection of non-military individuals against chemical attack. We must not assume that chemicals will not be used against our cities by our enemies. These hostile nations are greatly concerned with the possibility of chemical attack against their own cities and have been making careful anti-gas preparations for the past ten years or more.

One of the many German handbooks upon air defense, *Luftschutz Handbuch* by Ernst Denkler, urges, in the preface, a recognition of the dangers to the population from aerial attack and the necessity for education and providing in

advance proper measures for protection. By preparation "we can then remove a great part of the danger, yes, we can make it completely harmless." The preface ends with the following words in bold face: "*Aber Gasschutz und Gasdisziplin sind unerlasslich.*" (But gas defense and gas discipline are indispensable.)

The Japs, who are especially vulnerable to gas in their thickly populated island empire, have for years held gas-defense exercises in their large cities and have a well-developed civil defense scheme.

The great problem in any plan for protecting populations against air chemical attack is to prevent panic, disorganization, and delay in repair. Only most careful training and preparation will accomplish this.

There are two methods of defense: the active defense by the Air Force, assisted by anti-aircraft artillery, and passive defense which includes protection against gas.

In the protection of any civil population it is first necessary to divide noncombatants into groups, since different equipment and different training is required for each. This has already been done by our Office of Civil Defense. There will be a small group of people composing the active protective services and the larger group of passive population for whom the whole scheme is designed.

The active population is composed of members of the local fire department, police department, medical service, nurses, air raids precautions service, and certain anti-gas specialists. In addition there are those who are charged with the maintenance of the necessary public services, communications, light, power, transportation, and security. In most countries the active civilian protective service for gas defense includes

a group of protection supervisors or wardens, a first-aid group, degassing units, repair crews, and the public services.

The group termed protection supervisors are the air-raid wardens in our civil defense scheme. They will doubtless be responsible for the inspection of all individual and group protection. They should act as liaison agents, and as soon as a warning of an attack is given and during an attack, should lend their efforts to getting noncombatants into shelters and making sure that all provisions for group protection against gas are taken.

The duties of the first-aid group are obvious. It is composed of medical personnel and nurses. In addition to rendering first aid, this group may be charged with the operation of bathing units for individuals who have been exposed to agents of the mustard-gas type. An ambulance section for gas patients is desirable. The hospitals are a part of the civil protective service but are not included in this grouping, as they must carry on their regular work. They are to be considered and equipped, however, as a part of the active population.

The function of the degassing units also requires little explanation. They should be put to work cleaning up gassed areas as soon after an attack as possible. A signal will be given by sounding an "all clear" to indicate that the attack is over, and mopping up should be started. The signal must be differentiated from another one permitting civilians to leave their shelters.

Repair crews will generally work with the degassing units. As I visualize it, certain general repair crews will be required for opening up roads and repairing bridges, and should be under the direction of the local government. Large manufacturing plants, railroads, and public utilities should know

what to do about gas. The whole idea is to have an organization which will permit an early return to normal conditions after an attack, and to reduce casualties among the passive population to a minimum.

Individual protection is provided for everyone within the area of possible attack. The members of the civil defense agencies, that is, the *active* population, are equipped with service or heavy-duty gas masks and, where necessary, with protective clothing to keep blister-gas vapor from the skin. Civilian gas masks are provided for the *passive* population. These masks are simple in construction and easy to put on. They are being produced rapidly, and will be furnished by the government to all civilians in areas that may be subject to air attack.

Collective protection (the protection of groups of individuals) for the civil populations is extremely important. The civil problem is even greater than the military problem of collective protection, since the soldier is provided with the most complete and effective individual equipment. Most noncombatants, on the other hand, will have no special clothing to protect the body; and the noncombatant gas mask, although effective, is not intended for long protection against heavy concentrations but rather to permit the citizen to get out of the gas.

To prepare sufficient numbers of gas-proofed shelters in convenient places so that all may be taken care of quickly and without undue confusion, is a big problem. In Europe it has been found possible to shelter a large part of the civilian population even in the largest centers, but the problem is a tremendous one and requires careful preparation and complete organization.

In an attack from the air, people may be subjected to

both high explosives and gas. If it were not for high explosives, many safely might seek refuge in the upper stories of large buildings, or, perhaps, even the attics of their own homes where gas could not reach them. These places, however, would be the most dangerous if struck by high-explosive bombs. The best protection against both agencies is found in gas- and bomb-proofed cellars, basements, and subways.

Large cities offer special solutions of their own. Many of the buildings give protection against high explosive and gas if people assemble on certain floors high enough to be out of the way of the gas but yet not too high to be affected by high explosive bursting on the roofs. Three or four floors from street and roof is a good rule. In general, large-scale gas-proofing will be confined to underground spaces, or bomb-proofs. Gas-proofing without bomb-proofing is usually futile.

Spaces for group protection should be established in public buildings, and the gas-proofing of private dwellings should be carried out by individual home owners. Any place that is made gas-proof or bomb-proof must be inspected frequently in order to assure that the means of protection are in working order. This is accomplished by municipal authorities in buildings publicly owned. The inspection of small buildings will generally be carried out by the wardens.

Here it is well to take into account the fact that the sections of a city most likely to be attacked by enemy aircraft are those in the vicinity of railroads or railroad yards, public utilities or large manufacturing establishments. The bombing of residential areas will generally be incidental to an attack upon some key point, but experience has now shown that the workers' homes are frequently the target of area bombing by our enemies.

In order to provide for gas danger in large cities where hundreds of thousands of people live within a small area, the basements of all large apartment houses, school buildings, public libraries, and art museums should be bomb- and gas-proofed. Where a residential section comes in close contact with factories or other possible enemy targets, the number of gas-proofed shelters and bomb-proofs should be increased.

In gas-proofing, all window openings should be closed by wooden shutters and blankets, or some more elaborate seal, and air-lock entrances should be provided. As I have said, the air lock is simply a system of double doors so arranged that one door is always closed and no draft is permitted to enter the protected room. Glass windows will be broken by explosion and blankets alone may be blown in and torn. Hence, two layers of wood bolted together would be used to close large openings, with blanket seals covering the wood. In some cases windows and doorways may be bricked up, or sealed with plywood or plaster board and protected by sandbags. Complete directions are provided by the Office of Civilian Defense.

The question of ventilation becomes a serious one in an extensive gas attack, and in the larger installations some means of filtering the air will have to be provided. Large gas filters through which the outside air is drawn or blown can furnish purified air to enclosed spaces. Hospitals, communication centers, and those places set aside for the active protective services, especially will require ventilation of this kind. Commercial concerns in England, Germany, and Italy offered collective protectors for sale several years before the present war. Since they will be centers of activity during a gas attack, all places occupied by the active population must receive special

attention. Those places which are more likely to be attacked are generally the sections of the city where it will be possible to find suitable spaces for collective protection. Much thought has been given to the use of subways in a gas attack. If the ventilation problem can be solved, subways should be excellent protection against gas as well as high explosive. Large gas filters such as are used in coast defenses and on battleships will be required.

In the future construction of our large cities, thought should be given to protection against aircraft, and buildings should be designed so that places of refuge may be improvised without difficulty. In this connection the February, 1934 issue of *Revue Internationale de la Croix Rouge* carried the information that under the date of October 10, 1933, the Ministry of Finance of the German Reich published an order which gave very material financial reward to all persons who would establish protection against aircraft in their factories or buildings. Further, it provided for sharing the expenses incurred in transforming basements into protective shelters against aerial attack, and for replacing wood construction by iron and fireproof construction. Not only was the German government willing to share the expenses in connection with protective shelters, but it also provided a reduction of tax for those factories or buildings made safe against air attack. The preparation for this war by our enemies has been long and thorough and has been before us as a warning for years.

Thought must also be given by cities to the laying out of electric lines for power, light, and communication. It is especially essential that auxiliary underground power plants be available in our large cities. Every step should be taken to prevent the cutting of the water system.

Preparations must include not only gas-proofing, and bomb-proofing by means of sandbags and barricades, but also the equipment of shelters with food and other necessaries. Sanitary facilities will be essential, since gas-proofed shelters may have to be occupied until degassing operations are completed. In the spaces set aside for the active protective services, there must be kits of surgical instruments for emergency operations and ample stores of dressings and medical materials, degassing stores, and tools. All shelters for the passive as well as the active population should have emergency food and water supplies. The slogan might well be: Dig deep, equip well, and be comfortable as well as safe.

The problem is a tremendous one and the only answer to it is organization, education, and training. In many countries large-scale preparations started as long ago as 1928 and the instruction of the public has been under way for many years. The Royal Air Force saved Britain from destruction and conquest in the dark days after Dunkirk. It was the years of preparation, education, and training, however, that saved the nation from chaos, the people from despair, and kept the wheels of industry moving. The education of the people is the first thing required after an organization has been built up. Each community must provide and train its own organization for protection. It is important to reduce disorder and prevent panic. Education will accomplish this.

If an enemy should have sufficient aircraft and sufficient chemicals to drench an entire city with a heavy concentration of gas, adequate protection perhaps might not be practicable. Such an attack, however, is an improbability, although it will not be an impossibility. The objective will generally be a certain few key points. If we keep this fact in mind and design our protection especially to cover these points, the

practicable means of reducing casualties which we have developed will be effective and the disorganization, demoralization, and delay that an enemy desires will be greatly minimized, if not eliminated.

XVII

FIRST AID

AVOIDABLE or unavoidable, gas casualties do occur and a knowledge of the proper means of first aid should be possessed by everyone. The possession of this knowledge is an asset to the individual and to the nation, for the most important single factor in the treatment of gas casualties is prompt and intelligent first-aid measures. The timely administration of first aid may prevent death. For the cases less seriously affected first aid will shorten materially the time needed for recovery and will reduce suffering.

In applying first aid, intelligent treatment is as important as prompt action. It is necessary to know what things to avoid in the handling of gas casualties, since to do the wrong thing may be more serious than to do nothing. For example, it is far better in the case of a man seriously gassed with a lung irritant, to leave him on the ground covered with a blanket until he can be picked up by a stretcher bearer, than it is to help him walk to a first-aid station. In fact, walking may prove fatal.

Each chemical agent produces certain conditions which require special treatment. However, there are certain first-aid measures which are applicable to all gas cases and which, if applied early, will give relief. These are fresh air, rest, warmth, careful attention, and the neutralization of the chemical.

As soon as possible, a person suffering from exposure to any chemical agents or gases should receive the following general treatment:

1. Remove the patient immediately from the gas-infected area to a place where there is no contamination, preferably in the open air.
2. Remove any of the clothing which has been contaminated with the gas as soon as possible and substitute blankets or other covering to keep the patient warm. If clothing is not contaminated make sure that it is loosened and that the patient is as comfortable as possible.
3. Put the patient to rest in a comfortable position, either lying down, or partly propped up.
4. Apply warmth to the body, and if practicable, keep the patient in fresh air.
5. Neutralize the chemical. Wash the exposed body surfaces with soap and water to remove the chemical. Send immediately for an ambulance, a litter, or other transportation to convey the patient to a hospital or an aid station where he can receive proper attention.
6. Keep the patient absolutely quiet. Do not permit him to move about or to talk unnecessarily. If he has inhaled lung irritants, it is necessary to reduce the amount of oxygen which his body requires. Remember that oxygen is used up by any movement of the body.
7. If the patient has been burned by phosphorus, keep the burned areas covered with water—this is very important.

For specific first-aid measures it is most convenient to take up the various chemical agents in accordance with the physiological classification. First-aid measures for the choking gases are all very similar, and the same applies to the blister

gases and other classes. Consequently, if treatment is understood for the type agent, the same general treatment will apply for the other agents of the same type. Where there are differences between the agents in a class they will be given.

It should be noted that these instructions apply only to first aid and not to the definitive treatment that should be given later in a hospital or by a doctor. Only measures which are practicable in the field or the city street are discussed. The administration of oxygen, for example, would be a very desirable aid measure in serious lung cases, but it is obvious that oxygen equipment will rarely be available to the person applying first aid.

Choking Gases

The choking gases cause casualties by interfering with the action of the breathing apparatus. The inside of the lungs is made up of hundreds of thousands of tiny cells which gives a tremendous surface area. When breathed, the lung-irritant gas irritates the cells with which it comes in contact and causes a fluid to be given off. The doctors call this formation of fluid *oedema*. The fluid, which is taken from the blood, collects in the lungs and interferes with the action of the lung cells which normally transmit oxygen from the inhaled air to the blood. Thus, the amount of oxygen available to the body is decreased. This increases the work of the heart which pumps harder to supply enough oxygen to the body. Gradually, if the fluid increases, the air supply is cut down to such an extent that the victim suffocates. It might be said that he has actually drowned in his own fluid. All of this takes time, but most cases pass the critical point within twenty-four hours.

Phosgene is the type agent of the lung irritants and is the most dangerous of this class. It has little effect on any portion of the body except the lung cells, although there may be some irritation of the eyes, nose, and throat after exposure to high concentrations.

The first-aid measures for phosgene apply to all the other lung irritants. They are as follows:

1. Remove the patient immediately to pure air. Remove equipment and loosen clothing.
2. Make him lie down and keep him quiet in a reclining position. Do not allow a patient suspected of gassing with phosgene or any of the lung irritants to walk to a first-aid station even though he may feel able to do so. A lung irritant case must be treated as a stretcher case.
3. Cover with a blanket and keep patient warm. Absolute quiet, warmth, and plenty of air are very essential. It is necessary to conserve oxygen. Any movement uses up oxygen and should be avoided. Cold causes discomfort, shivering, and consequent movement which consumes oxygen.
4. Give light stimulant such as hot tea or coffee. Do not give alcoholic stimulant.
5. Strong concentrations of phosgene are very dangerous. Patient should be moved to hospital as soon as possible.
6. Do not attempt artificial respiration. Lungs affected with gas are seriously damaged and water-logged. Artificial respiration may do more harm than good, and even cause sudden death.

Chlorpicrin and chlorine are not as poisonous as phosgene, and larger amounts of these agents are required to cause death. The immediate symptoms are much more easily recognized than those of phosgene and consequently the patient

is more likely to get proper treatment without delay. Both of these gases irritate the nose and throat and cause violent coughing. Chlorpicrin also causes repeated attacks of vomiting and in addition has a very decided tear-gas effect. Splashes of chlorpicrin on the body should be washed off as soon as possible since they cause severe irritation of the skin and the formation of ulcers. Skin abrasions exposed to chlorpicrin vapor may become irritated and abscessed.

Since the effects of even fairly large concentrations of phosgene and diphosgene may be slow to show themselves, it is often difficult to recognize these gas cases in time to give the first aid which is so essential. Where there is any doubt, the patient should be asked to describe his own symptoms. Leading questions should not be asked. It may be that some symptoms such as vomiting have occurred. The man may have become unduly exhausted in getting to the place where he has been found. Evidence of this exhaustion may be furnished by pallor of his face and by rapid pulse. Examination should be made for any irritation of the eyes, coughing, or shallow and rapid breathing. Examine carefully to determine whether the man suspected of gassing can take a deep breath without discomfort or coughing. The cigarette test is perhaps as practical a test as can be made in the field. Offer the man a cigarette. If he smokes it without complaining that it tastes bad, or without coughing, or any other distress, the chances are that he has not been seriously gassed. If the cigarette has a bad taste it is an indication of gassing. This test was used during the First World War to detect malingering. It is possible, of course, to fake this test, but the benefit of doubt should be given the patient. Finally, it should be repeated, lung irritant casualties must be kept quiet and warm, and treated as stretcher cases.

Blister Gases

Mustard gas is the only vesicant with which there is any experience under war condition; it is the type agent of this class. Lewisite was not used as a war gas during the last war, and although there is evidence of its use against the Chinese, no data have been received as to the effectiveness of methods of treatment. From experience in the laboratory and in manufacturing Lewisite, it seems likely that in those cases where the agent is brought in direct contact with the skin Lewisite will be more difficult to deal with than mustard gas. In general, the effects of mustard gas and Lewisite are about the same, and the same *immediate* treatment is indicated for both.

Mustard gas produced more casualties during the World War than any other chemical agent. It should be kept in mind that it is dangerous in concentrations so low that the odor can barely be detected and that it destroys the sense of smell when small amounts are breathed for two or three minutes, so that a man may continue to be in a mustard-gas area without realizing it.

The action of mustard gas on the body is very slow since the agent secures its effect by entering the skin and gradually dissolves its way through, destroying the cells with which it comes in contact. It takes time to destroy these cells and the burning action is not noticed until from one hour to a day or more after exposure. With high concentrations the symptoms appear more rapidly, of course, and when they occur very soon after exposure the burns resulting will be severe. Burns produced by mustard gas are similar in appearance to, though often more severe than, extreme cases of sunburn. The symptoms, which usually do not appear until several hours after exposure to mustard gas unless there has been

direct contact with the liquid, are burning of the eyes, reddening of the exposed skin areas followed by blistering, and ulceration in more severe cases. Splashing with the liquid agent produces a gray splotch on the skin which appears within fifteen minutes. Breathing the gas causes hoarse coughing and severe pain in the chest. There is inflammation of the nose, throat, and entire breathing apparatus. If any of the gas has been swallowed, the stomach lining is affected and nausea, vomiting, and diarrhea result.

It is impossible to recognize gassing with mustard or Lewisite until the effects commence to appear. If a man has been exposed to a blister gas, however, first-aid measures should be applied at once without waiting for symptoms to develop. The first thing to do is to remove the vesicant promptly and completely.

If mustard-gas liquid or vapor can be removed from the skin within five minutes, no burn will result. If, however, the material is not removed completely within that time it enters the skin, and it is difficult if not impossible to prevent a burn.

Some years ago I was working with a number of the warfare gases at Edgewood Arsenal. I had filled a test tube with undiluted mustard gas and in a moment of carelessness upset the tube and spilled all of the mustard gas over my wrist and hand. While my assistant rushed to get some gasoline, which is an excellent solvent for mustard, I ran to the near-by water tap and let the water flow over my arm. Although water will not dissolve mustard gas, that action at least gave me something to do while waiting for the gasoline, and the mechanical action of the water would remove some of the mustard. Within three or four minutes a pail of gasoline was brought and poured over my wrist and hand until the bulk

of the agent had been dissolved off. Then my assistant scrubbed the affected parts with gasoline, using a clean cloth at each application so that none of the dissolved mustard would get back into circulation. This was repeated until it seemed that all of the mustard had been removed, and I went about my business.

A half an hour later I noticed a small spot on my uniform breeches above the knee, and at the same time detected a faint odor of mustard gas. Apparently a tiny drop of mustard gas had spilled on my breeches, or a drop of the gasoline containing mustard dissolved off my hand had dropped on the garment. I ran to my quarters, removed my clothes, and scrubbed my knee with gasoline, using ten separate applications. Then I took two hot baths using plenty of soap and paying special attention to scrubbing my knee. About four hours later I noticed a reddening like a sunburn on my leg. Mustard-gas treatment was applied at the laboratory. In spite of this the next morning I had a blister nearly two inches in diameter and one-fourth inch high just above my knee. A very slight redness was the only evidence that my wrist and hand had been affected. The mustard gas had been removed from my hand quickly enough so that none of it dissolved in the skin. One tiny drop, however, on my breeches worked its way through outer garments and underclothes to cause a serious and uncomfortable vapor burn in spite of expert treatment a few hours later. The lesson is, clearly, that immediate action to remove mustard gas is effective, but that delay in removing the agent is certain to cause a casualty.

For first-aid treatment it is necessary to use whatever solvent is available. Kerosene, gasoline, carbon tetrachloride ("pyrene" or "energene"), and alcohol are probably the best solvents, but petrolatum, acetone, olive oil, and lubricating

oils will also dissolve the vesicants. Following the solvent, the area should be carefully washed with soap and water. Strong laundry soap and water are excellent for removing blister gas.

Obviously, in wartime, hot water and soap and most of the various solvents may not be at hand in applying first aid. The important thing is to remove the gas as quickly as possible and one should not be too particular in trying to get the ideal solvent. It is best to take action at once with whatever is at hand. Gasoline or crank-case drainings may be obtained from a near-by truck or automobile. Perhaps lubricating oil will be more easily available than gasoline, or a near-by kitchen may provide olive oil or some other vegetable cooking oil. If oil is used, however, it should be applied copiously and great care used to wash it off completely as soon as possible with strong soap and water.

The most suitable material for removing mustard gas is a solution of carbon tetrachloride saturated with chlorine since this not only dissolves but neutralizes the chemical. Washing with sodium hypochlorite solution will also destroy the mustard. These materials, however, will not be available to the person rendering the first aid unless prepared ahead of time. An excellent neutralizing material which is readily obtained and should be kept on hand is bleaching powder (calcium hypochlorite). This must be made into a thin watery paste or solution before applying to the skin. Dry bleaching powder should not be placed directly on the skin if mustard gas is present since it reacts violently with mustard and the heat produced by the reaction will cause a severe heat burn.

The more thoroughly the skin is washed to remove the mustard the less injury is likely to result. In using solvents to remove the gas, it is necessary to use several fresh pieces of

cloth, one after the other, and continue the treatment as long as a half hour. Finally wash with hot soapy water. The eyes, nose, and throat should be washed as soon as possible with a saturated boric acid solution if available. A solution made by dissolving a level teaspoon of salt in a pint of water, or a heaping teaspoon of baking soda (be careful it is not washing soda) in a pint of water is also suitable.

An ointment for treatment of mustard gas has been developed by the Chemical Warfare Service and this ointment is issued to our armed forces. This ointment may be used to advantage after the bulk of the contamination has been wiped off, in the same manner as a solvent and should later be washed off with soap and water.

If a burn has already developed before it has been possible to give any first aid, ointment, bleaching-powder solution, or sodium hypochlorite should not be used as they will aggravate the burn.

The first-aid treatment for Lewisite is the same as for mustard gas except that water may be more useful in removing the agent. Immediate application of bleaching-powder solution is effective in preventing skin burns. The ordinary two per cent solution of hydrogen peroxide as sold at drug stores swabbed repeatedly on affected areas is a valuable preventive. Eyes should be washed with a two per cent solution of baking soda in water, or with plenty of plain water. Immediate and repeated application is necessary, especially if any liquid has touched the eyes. If sodium hydroxide (soda lye) can be obtained, a five per cent solution in water followed by washing with alcohol is effective in removing the agent from the skin. However, peroxide and sodium hydroxide may not often be available for first aid unless obtained in advance. Action to remove the liquid must begin within a minute to

be completely effective so whatever solvent is at hand must be used.

Lewisite acts much more rapidly than mustard gas, and the symptoms are noticed more quickly. Vomiting is likely to occur if any of the gas has been breathed. Lewisite skin burns appear as a grayish discoloration about one-half hour after exposure to the liquid. Since Lewisite contains arsenic, the hospital treatment for that agent must take this into account, and in that respect, the treatment differs from that for mustard gas.

In rendering first aid to vesicant cases, care must be taken to dispose of all contaminated equipment and clothing in such a way that no one else is affected. If a patient has mustard gas on his clothes, it constitutes a danger to anyone in the vicinity who is not completely protected with a gas mask and special gas-proof gloves and clothing. Many gas cases have been caused by contaminated equipment improperly handled. (*See page 274 for treatment for the new Nitrogen Mustards.*)

Tear Gases

First-aid treatment is seldom needed for tear gas, for the lacrimators rarely cause actual casualties. It is generally sufficient to get out of the tear-gas atmosphere and permit the outpouring of tears to wash the eyes.

The immediate effect of a trace of tear gas, such as CNS, in the air is to cause watering of the eyes, accompanied by smarting. With greater concentrations the smarting becomes an acute stabbing pain, which is so intolerable it is impossible to keep the eyes open. There may also be spasm of the eyelids. The profuse outpouring of tears and the pain will cause temporary inability to see, and will be quite enough to put a man completely out of action. Extremely high concentra-

tions of the tear gas are irritating to the nose and throat and may cause coughing. Infrequently, heavy concentrations of CNS and other tear gases will even cause nausea and vomiting.

CNS often causes an irritation of the skin and with some individuals who are especially sensitive produces a skin rash. This occurs very frequently in hot weather, especially on those parts where perspiration occurs—for example, around the collar. Under ordinary conditions there are no further effects and all of the symptoms clear up completely within a short time after getting into air free from tear gas.

After having experienced a severe attack the eyes may remain sore for several hours and there may be redness of the eyelids and eyes after twelve hours, but there are no subsequent poisonous effects and a man is fit for duty as soon as he can see without difficulty. Individuals who have never experienced tear gas before, may become frightened at the pain and temporary loss of vision and fear blindness. They can be assured, however, that their inability to see is only temporary and that the pain will soon pass away in the fresh air.

Persons affected by tear gas should get out of the tear-gas atmosphere and face into the wind. Let the tears flow freely and do not rub the eyes under any circumstances. It is difficult to obey the instructions to keep the hands away from the eyes. Rubbing the eyes increases the irritation and may rub tear gas which has settled on the hands or handkerchief into the eyes. The tiny particles of tear gas which have settled on the clothes and all parts of the body remain there until they disappear by evaporation or are washed off. Consequently, a man who has been in tear gas carries out of a tear-gas atmosphere considerable irritant on his person. This

will be evaporated rapidly in the fresh air, but until it does an irritating amount exists in his vicinity.

In aggravated cases the eyes may be washed with warm water or in a mild solution made by dissolving one teaspoonful of salt in a pint of water (normal saline solution) or a teaspoon of baking soda (be careful: *not* washing soda) in a pint of water. If available a saturated solution of boric acid is even more beneficial for flushing the eyes. Generally, however, the effects of tear gas will have entirely disappeared in the clear air before the solutions for washing the eyes can be located or made up. Where there is a persistent skin rash, washing with baking-soda solution is helpful, and a solution of baking soda or sodium sulfite in alcohol, if it can be obtained, is even more desirable for treatment of the skin.

Sneeze Gases

The irritant smokes or sneeze gases are in about the same class as the tear gases so far as first aid is concerned. The only real cure for a person affected by this class of compound is—time and sympathy. A person who has breathed a moderately heavy concentration of irritant smoke will suffer intensely for about twenty-four hours and there isn't much that can be done during that period. At the end of that time, however, the symptoms will disappear completely and there will probably be no after-effects.

The type agent of this class is DM (Adamsite). The first sensation in a light concentration of DM suggests the beginning of a cold. There is frequent sneezing and a watery discharge from the nose. The next symptoms produced are intense pain in the forehead which soon extends to the nose, face, teeth, and jaws; in fact, the man affected by DM feels

intense pain throughout his entire head. There is also irritation of the throat and a tightness and pain in the upper part of the chest. Next, there is a feeling of nausea, especially in heavier concentrations. Nausea is intense in bad cases and retching is of such severity that muscular weakness and sweating follow. Vomiting does not relieve the nausea and pain in the chest and an acute and very distressing mental depression is a particular feature of DM poisoning. Sometimes depression is so great that the patient attempts to destroy himself. A special watch must be kept to prevent this. It is difficult to realize that in not much more than twenty-four hours this extremely sick person is likely to be feeling perfectly well again, but this is generally the case.

The irritant smokes are not gases, but are fine particles of solid matter which have been suspended in the air. Therefore, they cling to the clothing and the body with a certain degree of persistence. Entry into a warm room after exposure may cause the air in the room to become somewhat unpleasant and, consequently, outer garments should be removed and shaken out before entering a building.

First-aid treatment for DM consists largely in removing the patient from the contaminated air and away from heat. It is helpful to flush the nose with salt water or baking-soda solution. Some relief is obtained by breathing weak concentrations of chlorine or the vapors from mixed alcohol, ether, and chloroform. Unfortunately, however, such materials will rarely be available to the person giving first aid. If chloride of lime (bleaching powder) is at hand, a small amount of this placed in a bottle will give off enough chlorine for the patient to breathe, especially after a little water is added to the chloride of lime.

The fact that little can be done to relieve the temporary

suffering, and the fact that the suffering is only temporary and normally passes away inside of twenty-four hours, may lead one to dismiss first aid for the irritant smokes too hastily. It should be remembered, however, that a severe mental depression must be combatted, and that the patient must be watched lest he do himself harm while suffering intense pain, combined with a nausea that by comparison makes ordinary seasickness a pleasant relaxation. Even though flushing the nose and throat with water may not give much relief, this action should be carried out since it gives the patient the comfort of knowing that something is being done for him.

Nerve and Blood Poisons

Breathing weak concentrations of AC (hydrocyanic or prussic acid) causes a somewhat unpleasant taste in the mouth, dizziness, headache, rush of blood to the head, tightness of the chest and throat, shortness of breath, and vomiting. With somewhat stronger concentrations, these symptoms are followed by weak and rapid pulse, rapid and shallow breathing, blueness of the lips and face (cyanosis), clammy skin, convulsions, unconsciousness, collapse, and death. Breathing of any but weak concentrations is always fatal and generally almost instantaneous. There is rarely any occasion for first aid for AC. The poison acts so rapidly that the patient is gone before the first aid can be administered. If the concentration has not been enough to kill, the person exposed may not be affected enough to require first aid; and if the concentration is heavy, first aid will be of no avail. Where the balance is such that death is not instantaneous and symptoms are manifested, treatment must be rapid. The patient should be removed immediately to fresh air, cold water

doused on his chest, and artificial respiration administered. Any further treatment such as administration of oxygen must be carried out where facilities are available. The patient should be kept warm.

Carbon Monoxide

Although carbon monoxide is not used intentionally as an offensive agent of chemical warfare, it is frequently encountered during peace and war conditions. It is one of the gases given off in the exhaust from motor vehicles and it is also liberated by the explosion of a high-explosive shell. Whenever fire burns with not enough air, carbon monoxide is produced. For example, a coke or charcoal fire in a poorly ventilated room produces dangerous quantities of this deadly gas which has neither odor, color, or taste. Artificial illuminating gas is largely carbon monoxide. When gas mains are broken by bombs, escaping gas may seep into near-by houses and cause injury. Symptoms of poisoning by this gas generally develop suddenly. Frequently the person affected does not have enough warning to get away from the gassed atmosphere.

In low concentrations the symptoms of carbon-monoxide poisoning are tightness and throbbing of the head, weakness of the legs, roaring in the ears, blurred vision, and nausea. The lips become blue and characteristic red blotches appear on the skin. This is followed by drowsiness and unconsciousness.

Carbon monoxide is very easily absorbed by the blood. It unites with the red coloring matter and thereby reduces the capacity of the blood to carry oxygen. Consequently, one of the first-aid measures is to get the patient into pure air

where he can have plenty of oxygen and keep him from any exertion that would use up oxygen.

With heavier concentrations the victim loses consciousness rapidly. He may first feel an intense headache with a roaring of the ears and blurred vision. As he attempts to get out of strong concentrations of gas he becomes dizzy and falls unconscious. Breathing then becomes rapid and uneven and blueness of the lips appears. Pulse and breathing weaken gradually and death follows rather slowly, but at this stage, surely.

First-aid treatment for carbon monoxide should be thoroughly understood by everyone since cases of poisoning are so frequent. As soon as the patient has been removed to fresh air he should be wrapped in blankets and kept warm and quiet, as in the case of phosgene poisoning, in order to reduce his requirements of oxygen. If breathing weakens, artificial respiration should be administered. At the same time it may help to rub the legs to assist circulation. If an oxygen inhalator can be obtained, oxygen should be given. Artificial respiration and administration of oxygen should be persisted in until it is certain that there is no hope for recovery. It may be necessary to administer the oxygen for considerably more than an hour. After a patient has been restored to consciousness, he must be watched closely since relapse often occurs and if not treated, is followed by death. Recovery from carbon monoxide poisoning is slow. *Remember that the ordinary gas mask does not protect against carbon monoxide.*

Phosphorus Burns

Burns from white phosphorus are generally severe and difficult to heal. When burning phosphorus comes in con-

tact with the skin, burning continues and the molten phosphorus is difficult to remove. In rendering first aid to phosphorus casualties the burned areas should be kept covered with water in order to make certain that the phosphorus does not start burning again. There is little that can be done to treat the burn until one can be sure that the phosphorus is entirely removed. If the wound is washed with warm water, the phosphorus will melt and can be wiped off with absorbent cotton or gauze, which should be handled carefully. After the phosphorus has been removed, the injury is treated like an ordinary burn. Where there is likely to be a need for treating phosphorus burns, first-aid equipment should include a bottle of three per cent copper sulphate. If this solution is applied for three minutes, any phosphorus particles with which it comes in contact will be copper-plated and may be removed easily by washing or with forceps.

Shock

Shock is a condition which may have to be reckoned with at the same time as gassing. It may occur after any severe injury, and is frequently encountered immediately following serious injuries. The face is pale and pinched and has an anxious, frightened appearance. The patient feels weak, faint, and chilly. The skin is cold, clammy, and covered with cold sweat. The pulse is weak, rapid, or irregular. The breathing is sighing and irregular. The patient may be unconscious.

A patient suffering from shock should be placed in a recumbent position with head slightly lowered. All tight clothing should be loosened, and every effort made to get him warm. He should not be moved while in the condition of shock. Stimulation with one-half teaspoonful of aromatic

spirits of ammonia in one-third glass of water, or well-diluted brandy is valuable. Warmth should be induced by wrapping him in blankets and by the use of hot stones, irons, bricks, or bottles filled with hot water. Always safeguard the patient against burns by wrapping the hot-water bottle or other object in cloth. His condition will be such that he may get a burn without feeling it.

The treatment of fainting is similar to the treatment of shock. In fainting, however, there is loss of consciousness. The patient's head should be lowered and the legs elevated, cold water should be sprinkled on the head and chest.

Artificial Respiration

The following directions are included for performing artificial respiration which seeks to imitate natural breathing. It should be performed in fresh air, the body kept warm and all tight-fitting articles of clothing about the neck, chest, and waist loosened.

1. Lay the patient on his stomach with arms extended as much as possible and with face turned to one side so that the nose and mouth are free for breathing. The patient's tongue should be drawn forward.
2. Kneel, straddling the patient's thighs and facing his head; rest the palms of the hands on the muscles of the small of the back, with fingers spread over the lowest ribs.
3. With the arms held straight, swing forward slowly so that the weight of your body is gradually, but not violently brought to bear upon the subject. This act should take from two to three seconds. Immediately swing backward so as to remove the pressure (requiring one to two seconds) returning to original position.

4. Repeat *deliberately twelve to fifteen times a minute* the swinging forward and back movement, thus allowing four to five seconds for each complete cycle.

5. Continue artificial respiration uninterruptedly until natural breathing is restored. This may require an hour or more.

6. Never give liquids by mouth until patient is conscious.

Treatment for Nitrogen Mustards

Treatment for the new nitrogen mustards is similar to that for the other vesicants but water is more useful. If liquid agent has entered the eye, it must be washed out immediately. Water from the canteen may be used for this purpose. The eye can be better irrigated by another person, but when no one is around to help, one must flush his own eye without delay. This is best done with the victim lying on his back, face up. The lower lid is pulled open and water is slowly and gently poured into the eye from the canteen. The eye should be moved from side to side, and up and down, during the washing, which should be continued for about 5 minutes.

If the liquid has contaminated the skin, it may be removed with protective ointment. Since the ointment merely dilutes and does not destroy nitrogen mustard, it is necessary as a final step to wash off the film of ointment with water, or preferably with soap and water. If the contamination is positively known to be due to nitrogen mustard, soap and water alone may be used for decontamination, but it is safer where doubt exists to use first the ointment, followed by soap and water. If redness has already appeared, the ointment should be omitted, and soap and water alone used. Blisters should not be opened until medical treatment is available.

Lung cases should be kept warm and quiet.

Appendix

Appendix

1. Description of Chemical Agents

The important properties of chemical agents, including classification and nomenclature, such as symbols and markings of munitions, are shown in the following tabulations. The initials C. W. S. are the abbreviation for Chemical Warfare Service.

BLISTER GASES

MUSTARD

Common name	Mustard gas.
Chemical name	Bis beta-chlorethyl sulphide $(ClCH_2CH_2)_2S$.
C. W. S. symbol	H.
Persistency, summer	1 to 4 days in open; 1 week in woods.
Persistency, winter	Several weeks both in open and in woods.
Tactical classification	Casualty agent.
Physiological classification	Vesicant—Blister Gas.
Odor in air	Like garlic or horseradish.
Melting point	14° C. (57° F.) (pure); 7°–10° C. (45° to 50° F.) (plant product).
Boiling point	228° C. (443° F.).
Volatility at 20° C. (68° F.)	0.57 oz./1,000 cu. ft. air.
Vapor pressure at 20° C. (68° F.)	0.110 mm. of mercury
Vapor density compared to air	5.4
Density of liquid at 20° C. (68° F.)	1.27.
Solvents for	Oils, PS, alcohol, carbon tetrachloride.
Action on metals	None.
Stability on storage	Stable in steel containers.

Action with water	Hydrolyzes very slowly, at ordinary temperature.
Hydrolysis products	HCl and $(HOCH_2CH_2)_2S$ (not toxic).
Physiological action	Is absorbed in skin or lung tissue, then produces burns.
First aid	Wash affected parts with kerosene or gasoline, then with strong soap and hot water; rub dry; rinse with hot clean water. The agent must be removed within 3-5 minutes to prevent a burn.
Odor detectable at	0.0013 oz./1,000 cu. ft. air.
Eye casualty concentration	1 hour exposure 0.001 oz./1,000 cu. ft.
Lethal concentration	10 minutes exposure 0.15 oz./1,000 cu. ft. (when breathed).
Method of neutralizing	Bleaching powder; 3 percent sodium sulfide (Na_2S) in water; steam; gaseous chlorine; or bury under moist earth.
Munitions suitable for use	Airplane spray, airplane bombs, 75-mm. guns, 105-mm. howitzer; 155-mm. howitzer, 155-mm. gun, chemical mortar, and land mines.
Marking on munitions	2 green bands–H or HS gas.
Protection required	Gas mask and protective clothing (eye shields).

LEWISITE

Common name	Lewisite.
Chemical name	Beta-chlorvinyldichlorarsine ($ClCH{:}\ CHAsCl_2$).
C. W. S. symbol	L.
Persistency, summer (dry)	24 hours in open; 4 or 5 days in woods.
Persistency, winter	1 week or more.
Tactical classification	Casualty agent.
Physiological classification	Blister gas.
Odor in air	Like geraniums, then biting.
Freezing point	−18.2° C. (0° F.).
Boiling point	190° C. (374° F.).
Volatility at 20° C. (68° F.)	4.5 oz./1 000 cu. ft. air.
Vapor pressure at 68° F.	0.395 mm. of mercury.
Vapor density compared to air	7.1.
Density of liquid at 20° C. (68° F.)	1.88.
Solvents for	HS; PS; oils; alcohol.
Action on metals	None.
Stability on storage	Stable in steel containers.
Action with water	Hydrolyzes rapidly.
Hydrolysis product	HCl, M 1 oxide (very toxic solid)
Physiological action	Is absorbed in skin or lung tissue, then burns and liberates M 1 oxide which poisons body.
First Aid	Wash copiously with oils, hot water and soap, then dry. First aid must be applied at once.
Odor detectable at	0.0014 oz./1,000 cu. ft. air.
Lethal concentration	10 min. exposure 0.12 oz./1,000 cu. ft. (breathed).

Method of neutralizing	Alcoholic sodium hydroxide spray.
Munitions suitable for use	Airplane spray, airplane bombs, chemical mortar.
Marking on munitions	2 green bands—L or M 1 gas.
Protection required	Gas mask and protective clothing (eye shields).
Marking on munitions	2 green bands—M 1 gas.
Protection required	Gas mask and protective clothing.

ETHYLDICHLORARSINE

Common name	Ethyldichlorarsine (German: Dick).
Chemical name	Ethyldichlorarsine ($C_2H_5AsCl_2$).
C. W. S. symbol	ED
Persistency, summer	1 to 2 hours in open; 2 to 6 hours in woods.
Persistency, winter	2 to 4 hours in open; 12 hours in woods.
Tactical classification	Casualty and harassing agent.
Physiological classification	Vesicant and sternutator.
Odor in air	Biting, irritant, somewhat fruity odor.
Melting point	−30° C. (−22° F.).
Boiling point	156° C. (312° F.).
Volatility at 20° C. (68° F.)	47 oz./1,000 cu. ft.
Vapor pressure at 68° F.	5.0 mm. of mercury.
Vapor density compared to air	6.5.
Density of liquid at 20° C. (68° F.)	1.7.
Solvents for	Ethyl chloride.
Action on metals	None.
Stability on storage	Stable.

Action with water .... Hydrolyzes slowly.
Hydrolysis product ...... Ethylarseneous oxide and HCl (hydrolysis product is poisonous if swallowed).
Physiological action ..... Vesicant; 1/6 as powerful as HS. A powerful sternutator; causes paralysis of the fingers.
First Aid .... Wash skin with warm sodium carbonate solution (washing soda).
Odor detectable at ...... 0.001 oz./1,000 cu. ft. air.
Minimum irritating concentration .... 0.004 oz./1,000 cu. ft. air (causes sneezing).
Lethal concentration ..... 10 minutes exposure 0.5 oz./1,000 cu. ft. air (by breathing).
Method of neutralizing ... Sodium hydroxide solution.
Munitions suitable for use. Artillery shell, chemical mortar, airplane spray, and bombs.
Marking on munitions.... 2 green bands–ED gas (if used).
Protection required ...... Gas mask and protective clothing.

NITROGEN MUSTARDS

A series of new war gases, the nitrogen mustards vary in physical properties but have essentially similar toxic properties. All of this series are vesicants, casualty producing, and persistent agents. The most volatile persists less than 2 hours, the least volatile approximately as long as mustard. Odors vary from slightly fishy to practically odorless. Volatility varies from much less to five times greater than that of H. Most of them are easily hydrolyzed by water. The products of hydrolysis are toxic.

CHOKING GASES

PHOSGENE

Common name .... Phosgene.
Chemical name .... Carbonyl chloride ($COCl_2$).
C. W. S. symbol .... CG.
Persistency, summer ..... 5 mins. in open; 10–20 mins. in woods.
Persistency, winter ...... 10 mins. in open; 30 mins. in woods.

Tactical classification	Casualty agent.
Physiological classification	Lung irritant—choking gas.
Odor in air	Like ensilage; fresh-cut hay.
Melting point	−118° C. (−180° F.).
Boiling point	8.2° C. (46.7° F.).
Volatility at 20° C. (68° F.)	6,370 oz./1,000 cu. ft. air.
Vapor density compared to air	3.4.
Vapor pressure at 68° F.	1,180 mm. of mercury.
Density of liquid at 20° C. (68° F.)	1.37.
Solvents for	Cl and PS.
Action on metals	Dry, none; wet, vigorous corrosion.
Stability on storage	Stable in dry steel containers.
Action with water	Hydrolyzes rapidly.
Hydrolysis product	HCl and CO_2.
Physiological action	Burns lower respiratory tracts; causes edema.
First Aid	Keep patient quiet and warm; give oxygen in severe cases; treat like pleurisy; administer heart stimulants; treat as stretcher case.
Odor detectable at	0.005 oz./1,000 cu. ft. air.
Minimum irritating concentration	0.05 oz./1,000 cu. ft. air.
Lethal concentration	10 minute exposure 0.5 oz./1,000 cu. ft. air.
Method of neutralizing	Steam hydrolyzes, alkalies and amines react with CG.
Munitions suitable for use	Livens projector shell; cylinders; chemical mortar; large airplane bombs.
Marking on munitions	1 green band—CG gas.
Protection required	Gas mask.

CHLORINE

Common name	Chlorine.
Chemical name	Chlorine (Cl_2).
C. W. S. symbol	Cl.
Persistency, summer	5 minutes in open; 20 minutes in woods.
Persistency, winter	Same as summer.
Tactical classification	Casualty agent.
Physiological classification	Lung irritant—choking gas.
Odor in air	Pungent.
Melting point	−102° C. (−152.5° F.).
Boiling point	−33.6° C. (−28.5° F.).
Volatility at 20° C. (68° F.)	19,369 oz./1,000 cu. ft. air.
Vapor pressure at 68° F.	4,993 mm. of mercury.
Vapor density compared to air	2.4.
Density of liquid at 20° C. (68° F.)	1.4.
Solvents for	CG, PS, CCl_4.
Action on metals	None if dry; vigorous corrosion if wet.
Stability on storage	Stable in iron cylinders.
Action with water	A little dissolves, forming HCl, HOCl and ClO_2.
Hydrolysis product	HCl; HOCl; ClO_2.
Physiological action	Burns upper respiratory tracts.
First Aid	Keep patient quiet, warm, and treat for bronchial pneumonia.
Odor detectable at	0.01 oz./1,000 cu. ft. air.
Minimum irritating concentration	0.03 oz./1,000 cu. ft. air (irritates throat).
Lethal concentration	10 minutes' exposure 5.6 oz./1,000 cu. ft. air.
Method of neutralizing	Alkali, solution or solid.

Munitions suitable for use	Mixed with CG and PS in cylinders and LP shells.
Marking on munitions	1 green band—CL gas.
Protection required	Gas mask.

CHLORPICRIN

Common name	Chlorpicrin (vomiting gas).
Chemical name	Trichlornitromethane (Cl_3CNO_2).
C. W. S. symbol	PS.
Persistency, summer	1 hour in open; 4 hours in woods.
Persistency, winter	12 hours in open; 1 week in woods.
Tactical classification	Harassing agent and casualty agent.
Physiological classification	Lung irritant and tear gas.
Odor in air	Sweetish, like fly paper.
Melting point	−69.2° C. (−92.4° F.).
Boiling point	112° C. (231.5° F.).
Volatility at 20° C. (68° F.)	165 oz./1,000 cu. ft. air.
Vapor pressure at 68° F.	18.28 mm. of mercury.
Vapor density compared to air	5.6.
Density of liquid at 20° C. (68° F.)	1.66
Solvents for	Chloroform, CG, chlorine.
Action on metals	Produces slight tarnish only.
Stability on storage	Stable for long periods in steel containers.
Action with water	Very slightly soluble.
Hydrolysis product	Hydrolyzes with difficulty.
Physiological action	Lacrimates, irritates nose and throat, produces nausea and lung irritation in order as concentration increases.

First Aid .... Wash eyes with boric acid; keep patient warm and protect throat from infection.
Odor detectable at .... 0.007 oz./1,000 cu. ft. air.
Intolerable concentration .... 3 minutes' exposure; 0.02 oz./1,000 cu. ft. air.
Lethal concentration .... 10 minutes' exposure; 0.05 oz./1,000 cu. ft. air.
Method of neutralizing .... Sodium sulfite solution.
Munitions suitable for use .... Mixed with CN in artillery shells; air bombs, chemical mortar shell; airplane spray. Mixed with CG in LP shells.
Marking on munitions .... 2 green bands—PS gas.
Protection required .... Gas mask.

DIPHOSGENE

Common name .... Diphosgene.
Chemical name .... Trichlormethylchlorformate ($Cl_3C\ COOCl$).
C. W. S. symbol .... DP.
Persistency, summer .... 30 minutes.
Persistency, winter .... 2 hours.
Tactical classification .... Casualty agent.
Physiological classification .... Choking gas.
Odor .... Smells like phosgene, but more irritating and choking.
Melting point .... −57° C. (− 70.6° F.).
Boiling point .... 127° C. (260.6° F.).
Volatility at 20° C. (68° F.) ...... 120 oz./1,000 cu. ft. air.
Vapor pressure at 20° C. .... 10.3 mm. of mercury.

Vapor density compared to air	6.9.
Density of liquid at 20° C. (68° F.)	1.65.
Action on metals	Same as phosgene.
Stability on storage	Stable in dry steel containers.
Action with water	Slowly hydrolyzes to form phosgene, HCl, and CO_2.
Physiological action	Burns lower breathing apparatus causing edema, irritates eyes.
First Aid	Same as phosgene.
Minimum irritating concentration	.005 oz./1,000 cu. ft. air.
Lethal concentration	Probably about the same as phosgene. German data, however, gives toxicity on 10-min. exposure .05 oz./-1,000 cu. ft. air.
Method of neutralizing	Same as phosgene.
Munitions suitable for use	Artillery and mortar shell; LP shell.
Protection required	Gas masks.

IRRITANTS (EYES AND NOSE)

ADAMSITE

Common name	Adamsite
Chemical name	Diphenylaminechlorarsine ($NH(C_6H_4)_2AsCl$).
C. W. S. symbol	DM.
Persistency, summer	5 minutes in open from candles.
Persistency, winter	5 minutes in open from candles.
Tactical classification	Harassing agent.

Physiological classification	Sternutator; irritant smoke.
Odor in air	No pronounced odor.
Melting point	195° C. (383° F.).
Boiling point	410° C. (770° F.). Decomposes below boiling point.
Volatility at 20° C. (68° F.)	Negligible.
Vapor density compared to air	No vapor; disseminated as solid.
Density of solid 20° C. (68° F.)	1.65.
Solvents for	Furfural, acetone.
Action on metals	Very slight.
Stability on storage	Stable in steel containers.
Action with water	Insoluble; hydrolyses slowly.
Hydrolysis product	HCl and DM oxide $[NH(C_6H_4)_2As]_2O$. DM oxide is very toxic if swallowed.
Physiological action	Headache, nausea, violent sneezing, followed by temporary physical debility.
First Aid	Breathe low concentrations of chlorine from bleaching powder bottle.
Odor detectable at	Almost no odor to average man.
Intolerable concentration	3 minutes' exposure 0.005 oz./1,000 cu. ft. air.
Lethal concentration	* 30 minutes' exposure; 0.65 oz./1,000 cu. ft. air.
Method of neutralizing	Gaseous chlorine; bleach liquor.
Munitions suitable for use	Candle, burning type shell or air bomb.

* Not obtainable in the open air.

Marking on munitions ....1 red band—DM gas.
Protection required ....Best type of smoke filter in gas mask canister.

NOTE. Adamsite and chloracetophenone may be mixed in burning type munitions. The physiological action is similar to that of both the components. Munitions suitable for use: grenades.

DIPHENYLCHLORARSINE

Common name ....Diphenylchlorarsine (German: Blue Cross and Clark I).
Chemical name ....Diphenylchlorarsine $(C_6H_5)_2AsCl$.
C. W. S. symbol ....DA.
Persistency, summer or winter .....5 minutes by HE detonation; 10 minutes by candle dissemination.
Tactical classification ....Harassing agent.
Physiological classification ....Sternutator; irritant smoke—sneeze gas.
Odor in air ....Like shoe polish.
Melting point ....44° C. (112° F.).
Boiling point ....383° C. (720° F.). Decomposes below boiling point.
Volatility at 20° C. (68° F.) ......Negligible.
Vapor density compared to air ....Practically no vapor; all solid particles.
Density of solid at 20° C. (68° F.)..1.4.
Solvents for ....Acetone, chloroform, chlorpicrin.
Action on metals ....Negligible.
Stability on storage ....Slowly decomposes.
Action with water ....Slowly hydrolyzes.

Hydrolysis product	HCl and DA oxide (DA oxide is poisonous if swallowed).
Physiological action	Sneezing, vomiting, headache.
First Aid	Breathe chlorine in low concentrations.
Odor detectable at	0.0003 oz./1,000 cu. ft. air.
Intolerable concentration	3-minute exposure 0.007 oz./1,000 cu. ft. air.
Lethal concentration	* 30 minutes' exposure 0.60 oz./1,000 cu. ft. air.
Method of neutralizing	Caustic; gaseous chlorine.
Munitions suitable for use	Burning type munitions.
Marking on munitions	1 red band—DA gas.
Protection required	Best type of smoke filter in gas mask canister.

DIPHENYLCYANARSINE **

Common name	Diphenylcyanarsine (German: Clark II).
Chemical name	Diphenylcyanarsine $(C_6H_5)_2AsCN$.
C. W. S. symbol	DC.
Persistency, summer or winter	5 minutes.
Tactical classification	Harassing agent.
Physiological classification	Irritant smoke—sternutator.
Odor	Irritant—suggestion of bitter almonds.
Melting point	31.5° C. (91° F.).
Boiling point	350° C. (662° F.).
Volatility at 20° C.	.0015 oz./1,000 cu. ft.

* Not obtainable in the open air.
** Reported to have been used in shells and bombs by Japs against Chinese.

Vapor density compared to air	8.8.
Density of solid at 20° C. (68° F.)	1.45.
Action on metals	Corrodes iron and steel.
Solvents for	Chloroform and organic solvents.
Stability on storage	Very stable.
Action with water	Practically insoluble.
Physiological action	Same as DM and DA but more intense.
Intolerable concentration on 10 minutes exposure	.0003 oz./1,000 cu. ft.
Method of neutralizing	Same as DM and DA.
First aid	Same as DM and DA.
Protection required	Best type of gas mask filter.

CHLORACETOPHENONE

Common name	Chloracetophenone.
Chemical name	Chloracetophenone or Phenylchlormethylketone ($C_6H_5COCH_2Cl$).
C. W. S. symbol	CN.
Persistency, summer	Solid persistent for days; burning mixture 5 minutes.
Persistency, winter	Several weeks in solid form; burning mixture 10 minutes.
Tactical classification	Harassing agent.
Physiological classification	Lacrimator—tear gas.
Odor in air	In low concentrations, like apple blossoms.
Melting point	59° C. (138° F.).
Boiling point	247° C. (476° F.).
Volatility at 20° C. (68° F.)	0.1 oz./1,000 cu. ft. air.

Vapor pressure at 68° F.	0.012 mm. of mercury.
Vapor density compared to air	5.2.
Density of solid at 20° C. (68° F.)	1.3.
Solvents for	Chloroform, PS, ethylene dichloride, monochloracetone.
Action on metals	Tarnishes steel slightly.
Stability on storage	Stable.
Action with water	None.
Hydrolysis product	Not readily hydrolyzed.
Physiological action	Eye and skin irritation.
First aid	Wash eyes with boric acid; wash skin with warm sodium bicarbonate solution (baking soda).
Odor detectable at	0.0002 oz./1,000 cu. ft. air.
Intolerable concentration	3 minutes' exposure 0.012 oz./1,000 cu. ft. air.
Lethal concentration	* 30 minutes' exposure 0.34 oz./1,000 cu. ft. air.
Method of neutralizing	Strong hot sodium carbonate solution.
Munitions suitable for use	Grenades; artillery shell; chemical mortar and bombs.
Marking on munitions	1 red band—CN gas.
Protection required	Gas mask.

CHLORACETOPHENONE SOLUTION

Common name	Chloracetophenone solution
Chemical name	A mixture containing CN, PS and $CHCl_3$ (chloroform).

* Not obtainable in the open air.

C. W. S. symbol	CNS
Persistency, summer	1 hour in open; 2 hours in woods.
Persistency, winter	6 hours in open; 1 week in woods.
Tactical classification	Harassing agent.
Physiological classification	Lacrimator–tear gas.
Odor in air	Like fly paper.
Melting point	Below $-20°$ C. ($-4°$ F.).
Boiling point	About 90° C. (194° F.).
Volatility at 20° C. (68° F.)	About 100 oz./1,000 cu. ft. air.
Vapor density compared to air	About 5.
Density of liquid at 20° C. (68° F.)	1.5.
Solvents for	None needed.
Action on metals	Tarnishes steel slightly.
Stability on storage	Stable in shell, grenades, etc.
Action with water	None.
Hydrolysis product	Does not hydrolyze.
Physiological action	Causes violent eye irritation, vomiting, skin itching.
First aid	Wash eyes with boric acid, skin with sodium bicarbonate solution.
Odor detectable at	0.007 oz./1,000 cu. ft. air.
Intolerable concentration	3 minutes' exposure 0.02 oz./1,000 cu. ft. air.
Lethal concentration	10 minutes' exposure 3.8 oz./1,000 cu. ft. air.
Method of neutralizing	Hot solution of sodium carbonate and sodium sulfite.
Munitions suitable for use	75-mm., 155-mm., 4.2-CM shells; small air bombs; airplane spray; and explosive-type hand grenades.

Marking on munitions .... 1 red band–CNS Gas.
Protection required .... Gas mask.

NOTE. Chloracetophenone may also be dissolved in equal parts of benzene and carbon tetrachloride (10 percent CN, 90 percent solvent) to form a liquid known as CNB. Physiological properties are the same as solid CN. Persistency 6 to 12 hours.

BROMBENZYLCYANIDE

Common name	Brombenzylcyanide (French-camite).
Chemical name	Brombenzylcyanide ($C_6H_5CHBrCN$).
C. W. S. symbol	BBC.
Persistency, summer	Several days.
Persistency, winter	Several weeks.
Tactical classification	Harassing agent.
Physiological classification	Lacrimator–tear gas.
Odor in air	Like sour fruit.
Melting point	25° C. (77° F.).
Boiling point	247° C. (476° F.).
Volatility at 20° C. (68° F.)	0.13 oz./1,000 cu. ft. air
Vapor pressure at 20° C. (68° F.)	0.012 mm. of mercury.
Vapor density compared to air	6.6.
Density of solid at 20° C. (68° F.)	1.47.
Solvents for	Chlorbenzene, chloroform, PS.
Action on metals	Very corrosive to iron; lead or enamel lined shells required.
Stability on storage	Slowly decomposes.
Action with water	Slowly hydrolyzes.
Hydrolysis product	HBr/ and various compounds.

Physiological action	Causes severe lacrimation and nose irritation.
First aid	Wash eyes with boric acid solution.
Odor detectable at	Irritates before odor can be detected.
Intolerable concentration	3 minutes' exposure 0.0008 oz./1,000 cu. ft. air.
Lethal concentration	30 minutes' exposure 0.9 oz./1,000 cu. ft. air.
Method of neutralizing	Alcoholic sodium hydroxide spray.
Munitions suitable for use	75-mm. artillery shell or airplane spray.
Marking on munitions	1 red band–BBC gas.
Protection required	Gas mask.

NERVE AND BLOOD POISONS

HCN

Common name	Prussic acid.
Chemical name	Hydrocyanic acid (HCN).
C. W. S. symbol	AC.
Persistency, summer	5 minutes in open, slightly longer in woods.
Persistency, winter	10 minutes.
Tactical classification	Casualty agent.
Physiological classification	Nerve and blood poison.
Odor	Resembles bitter almonds.
Freezing point	−15° C. (5° F.).
Boiling point	26° C. (79° F.).
Volatility at 20° C. (68° F.)	873 oz./1,000 cu. ft. air.
Vapor pressure at 68° F.	603 mm. of mercury.
Vapor density compared to air	0.93.

Action on metals	Dry — none; corrosive, if wet.
Stability on storage	Unstable unless inhibited by strong acid or otherwise stabilized.
Action with water	Mixes readily and slowly decomposes.
Physiological action	Paralyzes central nervous system.
First aid	Artificial respiration, cold water to nape of neck, injections of ether or caffeine.
Odor detectable at	.001 oz./1,000 cu. ft. air.
Lethal concentration	0.20 oz./1,000 cu. ft. air on 10 minutes' exposure.
Munitions suitable for use.........	Livens projector shell; thin-walled bombs; large-capacity mortar shell; frangible grenades.
Protection required	Gas masks.

SMOKES

WHITE PHOSPHORUS

Common name	White phosphorus.
Chemical name	White phosphorus (P) (yellow phosphorus).
C. W. S. symbol	WP.
Persistency	Depends upon size of burning particle; usually 10 minutes or less in open.
Tactical classification	Screening agent.
Physiological classification	None.
Odor in air	Like matches.

Melting point	44° C. (111° F.).
Boiling point	About 290° C. (553° F.).
Density of solid at 20° C. (68° F.)	1.83.
Solvents for	Carbon disulfide.
Action on metals	None.
Stability on storage	Stable, out of contact with oxygen.
Action with water	None; stored under water in concrete tanks.
Smoke in air	Phosphoric acid (H_3PO_4) dissolved in water.
Physiological action	Solid particle burns flesh; vapors are very poisonous, causing bone decay; smoke relatively harmless.
First aid	Apply copper sulfate solution ($CuSO_4$) (2 to 5 percent). Pull out solid particles and treat like an ordinary burn. Keep burning part under water until medical attention arrives if no $CuSO_4$ is available.
Weight in ounces per 1,000 cu. ft.	Standard smoke, 0.06.
Cost in cents per 1,000 cu. ft.	Standard smoke, 0.21.
Method of neutralizing	None needed. Copper sulfate solution stops burning of particles, as does water.
Munitions suitable for use	Grenades; artillery shells; chemical mortars; airplane bombs.
Marking on munitions	1 yellow band—WP smoke.
Protection required	None needed against smoke. Fireproof suits against burning particles.

HC MIXTURE

Common name	HC mixture.
Chemical name	Hexachlorethane (C_2Cl_6) + zinc (Zn) + ammonium perchlorate (NH_4ClO_4) + ammonium chloride (NH_4Cl) + calcium carbonate ($CaCO_3$).
C. W. S. symbol	HC.
Persistency	Only while burning.
Tactical classification	Screening smoke.
Physiological classification	None.
Odor of smoke in air	Acrid, suffocating when very dense.
Melting point (C_2Cl_6 only)	184° C. (363° F.).
Boiling point (C_2Cl_6 only)	185 (sublimes) (365° F.).
Density of solid at 20° C. (68° F.)	2.0.
Solvents for	Alcohol ether (for hexachlorethane only).
Actions on metals	None, if dry.
Stability on storage	Stable.
Action with water	Mixture decomposes.
Smoke in air	($ZnCl_2$) zinc chloride in water solution.
Physiological action	None from solid; slightly suffocating action by heavy smoke.
First aid	None needed.
Weight in ounces per 1,000 cu. ft.	Standard smoke, 0.12.
Cost in cents per 1,000 cu. ft.	Standard smoke, 0.66.
Method of neutralizing	None needed.

Munitions suitable for use	Burning type munitions only; grenades, candles, smoke floats, special air bombs.
Marking on munitions	1 yellow band—HC smoke.
Protection required	None needed. If burned by munitions, treat like ordinary burn.

SULPHUR TRIOXIDE SOLUTION (FS)

Common name	Sulfur trioxide solution (or FS).
Chemical name	Sulfur trioxide (SO_3) about 55 per cent; chlorsulfonic acid ($HClSO_3$) about 45 percent (by weight).
C. W. S. symbol	FS.
Persistency	While container is operating.
Tactical classification	Screening agent.
Physiological classification	None.
Odor in air	Acid or acrid.
Melting point (or freezing point)	−30° C. (−22° F.).
Boiling point	About 80° C. (decomposes).
Density of liquid at 20° C. (68° F.)	Nearly 2.0.
Solvents for	Strong sulphuric acid.
Action on metals	Vigorous corrosion in presence of moisture.
Stability on storage	Stable in steel containers.
Action with water	Reacts violently like strong sulphuric acid.

Smoke in air	Hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) mixed, in water solution, as fog particles.
Physiological action	Liquid burns like strong acid. Smoke causes pricking sensation on skin.
First aid	Like an acid burn.
Weight in ounces per 1,000 cu. ft. standard smoke	0.12.
Cost in cents per 1,000 cu. ft. standard smoke	0.05.
Method of neutralizing	Any alkali, solid or in solution.
Munitions suitable for use	From cylinders under gas pressure; airplane spray tanks; explosive shell.
Marking on munitions	1 yellow band—FS smoke.
Protection required	None for ordinary smoke. Gas mask for high concentrations only. Rubber gloves for handling the liquid.

TITANIUM TETRACHLORIDE

Common name	FM.
Chemical name	Titanium tetrachloride ($TiCl_4$).
C. W. S. symbol	FM.
Persistency, summer and winter	10 minutes in open.
Tactical classification	Screening agent.
Physiological classification	None.
Odor in air	Acrid.
Melting point	−30° C. (−22° F.).

Boiling point	136° C. (277° F.).
Density of liquid at 20° C. (68° F.)	1.7.
Solvents for	Ethylene dichloride.
Action on metals	Vigorous corrosion by the smoke; none by liquid on steel if dry; vigorous corrosion if moist.
Stability on storage	Stable in steel containers.
Action with water	Hydrolyzes.
Smoke in air	$TiCl_4 . 5H_2O$ then HCl and $Ti(OH)_4$.
Physiological action	Liquid burns like strong acid; vapors and smoke irritating to throat.
First aid	Wash with sodium bicarbonate solution then with warm water and treat like an ordinary burn.
Weight in ounces per 1,000 cu. ft.	Standard smoke, 0.15.
Cost in cents per 1,000 cu. ft.	Standard smoke, 0.28.
Method of neutralizing	Alkaline solution.
Munitions suitable for use	Artillery shell; chemical mortar; airplane spray; airplane bombs; special munitions.
Marking on munitions	1 yellow band–FM smoke.
Protection required	None for ordinary smoke clouds; gas masks needed for heavy concentrations only.

CYANOGEN CHLORIDE

Chemical name	Cyanogen Chloride ($CNCl$)
Persistency, summer	10 min. in open. Slightly longer in woods.
C. W. S. symbol	CC
Persistency, winter	20 minutes.
Tactical classification	Casualty agent.
Odor in air	Sharp—penetrating.
Freezing point	6.5° C.
Boiling point	12.5° C.
Volatility at 20° C. (68° F.)	3,300 oz./1,000 cu. ft. air.
Vapor density compared to air	2.1
Action with water	Very soluble. Water favors polymerisation.
Physiological action	Systemic poison and eye and lung irritant.
First aid	Similar to AC.
Odor detectable at	.0025 oz./1,000 cu. ft. air.
Intolerable concentration	.05 oz. /1,000 cu. ft. air.
Lethal concentration	4 oz./1,000 cu. ft. air, on 10 minutes' exposure.
Munitions suitable for use	Airplane bombs; chemical mortar shell.
Protection required	Gas mask.

2. Use of Civilian Gas Mask

To Put on the Mask: Everyone should develop skill in putting on the gas mask. The important thing is to secure a protecting adjustment with the least confusion and most effectiveness. This requires repeated practice so that in an emergency movements will be automatic and instinctive.

At the command "Gas," stop breathing. Remove head covering and hold it between knees. Hold bottom of carrier with left hand and draw facepiece out with right hand. Bring facepiece in front of the face, chin high. Grasp facepiece with both hands, and bring in front of face. Stick out chin.

Dig chin firmly into facepiece, holding head stationary. Sweep head harness smoothly over the head. Seat facepiece firmly on the face with palm and fingers.

Close outlet valve tightly with palm or fingers and blow out to clear mask of any gas caught in facepiece. Recheck and adjust seating of head harness. Resume breathing. Replace head covering.

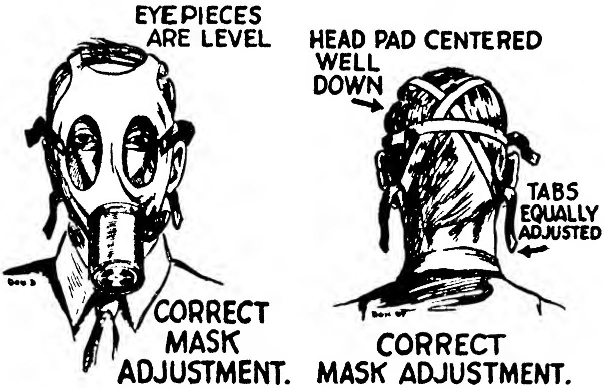
To Remove Gas Mask: To remove mask grasp top of canister and with an outward and upward motion pull facepiece clear of chin and then up over head.

Replace mask in carrier by sliding canister in first and in such a way that eyepieces face to front.

To Test for Gas: Take moderately full breath, bend down but do not kneel. Insert two fingers between facepiece and cheek. Sniff gently. If gas is detected, withdraw fingers and blow out hard. Readjust facepiece.

To Check Mask: With mask adjusted, close inlet valve at bottom of canister tightly with palm of hand. Inhale. Facepiece should collapse and cling to the face. If facepiece does not collapse, incorrect adjustment or improper fit is probable. Try adjusting head harness. If this does not prevent leakage of air into

mask, make sure that air is not passing between edge of face-piece and face due to incorrect fit, and then make careful inspection for leaks.



In choosing the size of a mask, the eyes should be about two thirds of the way up in the lens, so as to give the best vision. The tabs of the head harness should not be pulled up so tight as to cause headaches. However, they must be adjusted tight enough so that no leakage occurs.

CORRECT MASK ADJUSTMENT

3. *Care of Gas Masks: Service and Civilian*

Keep head harness as loose as possible without losing the fit (the tendency is to keep it too tight, thus breaking the elastic or tearing off buckles and tabs, and causing discomfort).

Avoid undue stretching of head harness in adjusting mask.

Do not throw the mask around, or use roughly.

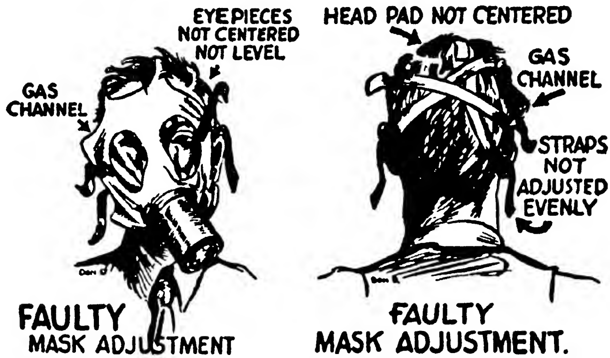
Do not put anything in carrier except gas mask unless instructed to do so by proper authority. Certain small protective articles such as ointment and cape may be carried in carrier when authorized.

Keep mask and carrier dry; dry out immediately after using and before repacking.

Make repairs promptly.

Store the mask in a cool, dry place.

Do not store in sunlight or adjacent to radiators, stoves, or furnaces.



If the headharness of the mask is incorrectly adjusted so that the opposing straps are not exerting equal pressure, wrinkles and channels along the side of the face will probably occur, and as a consequence, gas can then leak between. Figures show the front and rear views of faulty mask adjustment.

FAULTY MASK ADJUSTMENT

Do not store when either the mask or carrier is damp.

During storage keep a faceform in facepiece, or stuff facepiece with newspapers to prevent creasing.

Keep mask where it will not be damaged by a blow or heavy weight.

If adhesive tape becomes loose replace promptly before rust begins on binding wire.

Repaint the canister whenever necessary to prevent rusting.

The gas mask should be inspected for:

General cleanliness.

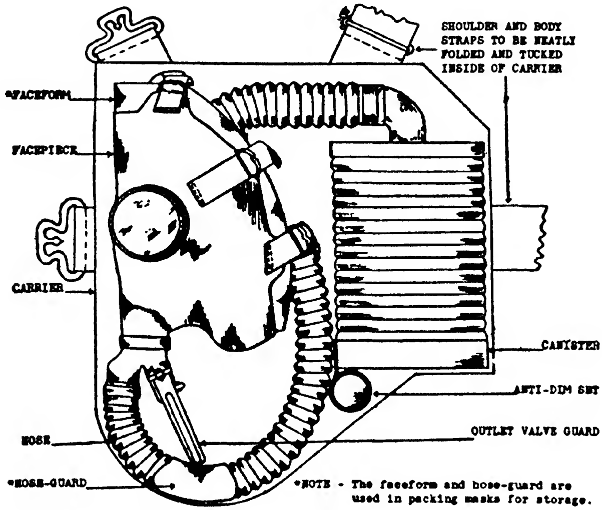
Fit.

Missing, loose, or defective parts.

Rust spots and other noticeable defects in the canister.

Holes, tears, and rips.

Defect in operation of outlet valve on facepiece or inlet valve on canister.



HOW GAS MASK IS PLACED IN THE CARRIER

Always replace the gas mask properly. Avoid creasing or kinking of the hose before replacing in carrier.

Permanent set in any rubber parts which may produce a poor fit.

Strength of elastic head harness.

Unauthorized articles in the carrier.

4. *Disinfection of Gas Masks*

Whenever masks are stored, exchanged, or used by more than one individual or when the wearer has been suffering from a cold, they should be thoroughly disinfected immediately after use.

A. MATERIALS REQUIRED.

1. *Green Soap Solution.* A solution of green soap is made by adding liquid green soap to a strong alcohol solution. Have a supply of small rags or rifle cleaning patches. This solution can be used on masks having either plastic or glass eyepieces.

2. *For Masks Having Glass Eye Lenses.* A two per cent solution of cresol or lysol, made by stirring three ounces of cresol or lysol with one gallon of water; a supply of small rags or rifle cleaning patches. A small quantity of solution may be made by adding two big teaspoonfuls of lysol to a pint of water and stirring.

3. *For Masks Having Plastic Eye Lenses.* A three per cent solution of formaldehyde made by adding one part of U.S.P. formalin (forty percent strength formaldehyde solution) to twelve parts of warm water, or one-half pint of formalin to three quarts of water. The formalin solution should be added slowly with stirring.

B. DIRECTIONS.

1. In disinfecting a gas mask, the facepiece should be kept lower than the canister to prevent the disinfectant from running into the hose or canister. Hold the mask in the hand, saturate a small piece of clean rag with the disinfectant, and sponge the entire surface of the facepiece, including the outer and inner side of the deflector. (In this operation the facepiece should not be turned inside out.) Then apply the disinfectant similarly to the outside of the outlet valve.

2. Squeeze a few drops of the disinfectant from the rag into the exit passage of the angletube of the service mask or directly into the outlet valve of the noncombatant mask. Press the sides of the outlet valve with the thumb and finger so as to let the disinfectant run out. Do not shake off the excess.

3. Allow all disinfected parts to remain moist for about fifteen minutes and then wipe out the inside of the facepiece with a

clean dry rag. The mask should dry thoroughly in the air before it is returned to the carrier.

CAUTION: Formaldehyde in high concentration causes a smarting of the eyes and nose. Disinfection of masks when formaldehyde is used should be conducted outdoors if practicable, the operator standing in the upwind side of the formaldehyde solution container. When it is necessary to disinfect masks indoors, good ventilation must be assured; and when this is not possible, personnel involved should wear gas masks. In all cases, personnel carrying out disinfection with formaldehyde solution must wear rubber gloves. After the masks have been disinfected, they should be exposed to free circulation of air for at least twelve hours in order to allow evaporation of the formaldehyde solution from the rubber.

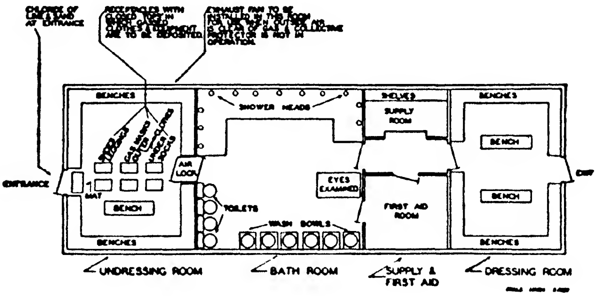
In disinfecting large numbers of masks in which cresol solution is used as the disinfecting solution, rubber gloves should be worn to protect the hands. If cresol solution is made stronger than directed it will cause irritation of the skin when mask is worn.

5. *Use and Care of Protective Clothing*

Putting on Clothing: In donning complete protective clothing, garments are put on in the following order: undershirt, drawers, socks, outer garments or coveralls, shoes, leggings, gas mask, hood, cotton gloves, and finally, if required, rubber gloves. Sleeves of both undershirt and coveralls should be pulled well down and covered by the wristlets of the cotton gloves. Hoods should be fastened tightly around the mask so that no vapor can come in contact with the neck or head. The hood is buttoned down to the back of the coveralls so the back of the neck will be protected.

Removing Clothing: Care is necessary in removing protective clothing which has been subjected to possible contamination. A

special room or tent should be provided with a bench on which to sit. On the floor at either side of the bench, paper will be placed. Remove leggings and shoes and stand on paper. Keep on cotton gloves. Next, without removing gloves, take off hoods, masks, and coveralls. Gloves, underwear, and socks are then removed. Men should immediately enter an adjacent shower room or field bathing unit and using plenty of strong soap take a



DECONTAMINATION STATION–FLOOR PLAN FOR DEGASSING OF PERSONNEL

thorough bath. They then avoid the undressing area and put on clean clothing.

Contamination: The individual should avoid contact with liquid mustard gas on vegetation even when wearing protective clothing.

Chlorinated lime: Especial care should be exercised by personnel to prevent chlorinated lime in any form, either solid or slurry, from coming into contact with permeable protective clothing as the chloride of lime will destroy fabric.

Organic solvents: Contact with organic solvents such as alcohol and gasoline should be avoided.

Holes: Care should be taken that no tears or holes are made in garments through which vesicant vapors might reach the body.

Examination before wearing: Men should inspect each garment before wearing it to insure there are no holes.

Storage of Protective Clothing: Protective clothing should be stored in a cool, dry, well-ventilated storeroom. Impermeable clothing should be stored without folding insofar as possible, since folding will crease the cloth and tend to break the material, thereby causing leaks. In the field these storage conditions should be followed as closely as facilities permit.

Minor Repairs. a. Permeable clothing: When holes or tears are detected in permeable garments they should be carefully patched with the same type of material. The mending material must be chemically treated to prevent vapors penetrating through the repairs.

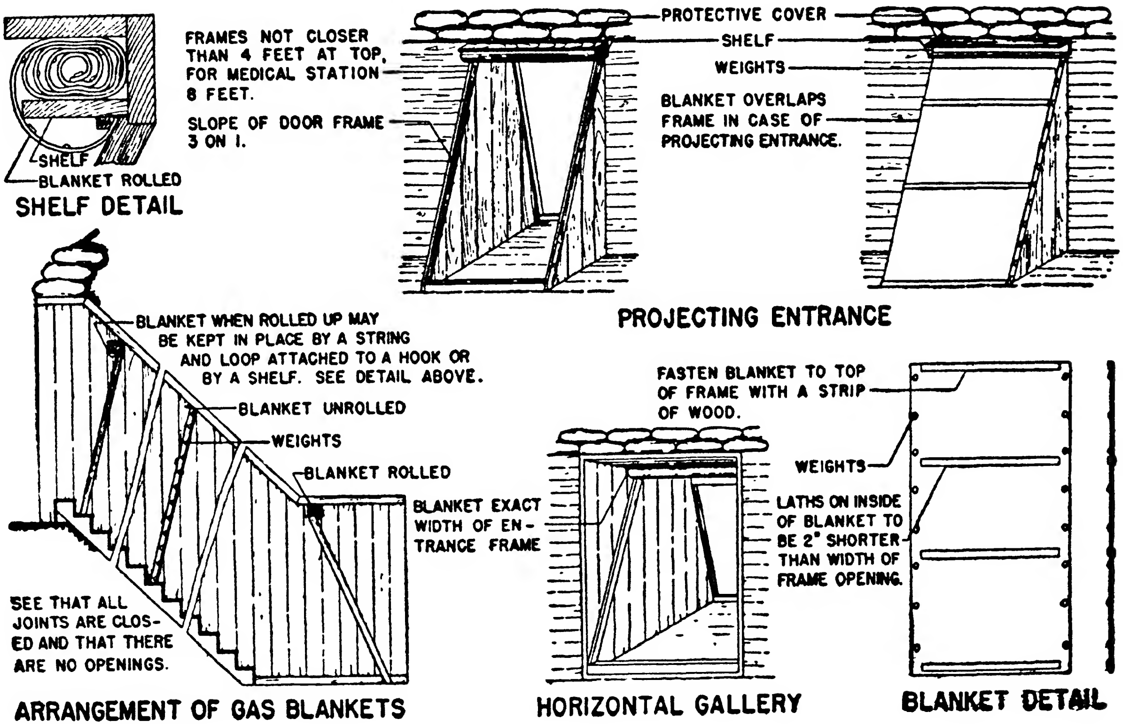
b. Impermeable clothing: Impermeable clothing when torn should have a patch of impermeable material sewed firmly in place. Rubber cement may be applied to the under surface of the stitching to make the thread impermeable. Zinc oxide or cellulose tape may be used in an emergency. This is best applied on the under surface also.

6. *How to Gas-Proof a Shelter*

During extended gas attacks men must be enabled to work and rest inside shelters with their gas masks off. This is most important in shelters where men are placed pending evacuation who are so wounded that they cannot wear a gas mask, in shelters used for medical dressing stations, telephone centrals, air-raid precautions centers, headquarters, and activities whose efficiency would be considerably reduced by wearing the gas mask.

The illustration of a Typical Arrangement for Gas-Proofing Dugouts shows details for gas-proofing. Door frames and sills against which blankets rest should be covered with strips of blanket material to assure tight closure.

Judgment should be used in cutting blankets to the proper size in an opening. Weights made from nuts, washers, scraps of iron, bullets, etc., are fastened along the side edges of the cur-



TYPICAL ARRANGEMENT FOR GASPROOFING

tain. Gas curtains should clear the side lagging by one-half inch and the floor by one and one-half inches when placed in horizontal entrance approach. When not in use the blanket is rolled up and placed on the shelf at the top of the frame.

There should be two gas curtains in every entrance in order to make an air lock or space between the two and permit entry and exit during attack without allowing an appreciable amount of gas to get into the shelter. The curtain frame should be set on a slope of three on one. Whenever possible curtain frames should slope in opposite directions with curtain on the outside. The space between the two blankets should be as great as possible in order to secure maximum dilution of the gas which will inevitably get in. In first-aid stations curtains are placed at least eight feet apart or at top and bottom of the incline. In short horizontal entrances where the curtains are necessarily closer to one another, the space should be as great as possible and never less than four feet at the top.

Curtains may be made for windows in the same manner as for entrances, except that only one curtain need be installed. Any openings should be filled with clay, old clothes, or sandbags. All crevices should be calked with pieces of blanket. If a shelter is not practically gas-tight, all pretense of protection should be removed.

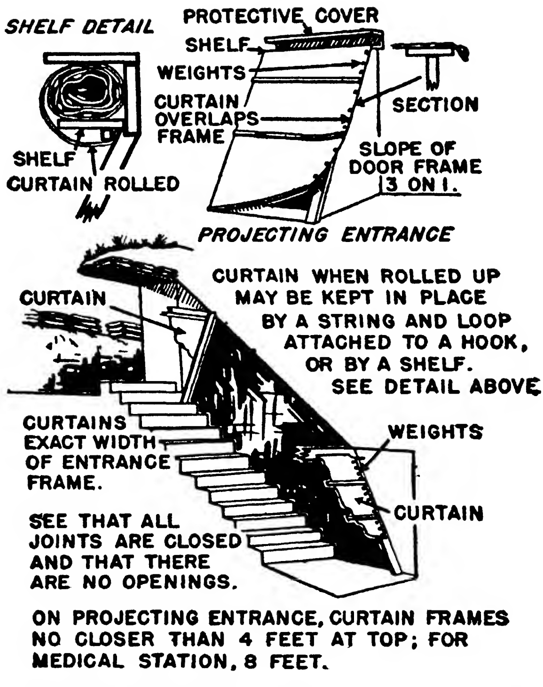
Flooring or steps in front of gas curtain should be kept clear of mud or refuse. The seal between curtains and frames is more effective if the curtains and frames are kept moist at all times. They should be sprayed daily. A pail or other container filled with fresh chloride of lime should be kept on hand at all times in gasproof shelters. During gas attacks or when men have been exposed to gassed terrain, the chloride of lime container should be opened and placed in the gas trap between the curtains for use of all personnel entering the shelter to destroy mustard gas on the feet or hands. Mustard gas or similar agent carried in soon converts the shelter into a gas trap.

MATERIAL LIST GASPROOF SHELTERS

Item	Size	Unit	Quantity
Curtain:			
Blanket	6′ x 7′	Each	1
Tacks	......	Package	2
Nails	Tenpenny	Pound	2
Small weights	......	Each	16
Laths	½″ x 1″ x 2′ 8″	Each	2
Laths	1½″ x 1″ x 2′ 2″	Each	2
Bottom strip	1″ x 2″ x 2′ 8″	Each	1
Top cleat	1″ x 2″ x 2′ 11″	Each	1
Frame:			
Frame pieces, front ..	2″ x 4″ x 16′	Each	1
Sash	1″ x 4″ x 16′	Each	1
Molding	1″ x 2″ x 16′	Each	1
Top and shelf	1″ x 6″ x 8′	Each	1
Furring	1″ x 2″ x 12′	Each	2
Nails	Tenpenny	Pound	1
Nails	Twentypenny	Pound	2

Floor Space. The following table gives data from which amount of shelter construction necessary may be approximated:

	Square Feet
Per man	9 to 12
First-aid station, per litter	28
Command post:	
Platoon	100
Company	200
Battalion	400
Regiment	600
Brigade	800
Division	1,600



GAS-PROOFING DUGOUT ENTRANCE

7. *Number of People to Be Accommodated in Gas-Proofed Shelters*

Unventilated Shelters

An allowance of 75 sq. ft. surface area (floor, ceiling, and walls), 160 cu. ft. of air space, and 6 sq. ft. of floor space is required for each person in a shelter which is not supplied with purified air when occupied for periods up to 3 hours under summer conditions. For periods longer than 3 hours, 100 sq. ft. of surface area and at least 200 cu. ft. of air space should be allowed per person. The following table may be used as a guide for the number of occupants that may be accommodated safely in an unventilated shelter.

Dimensions of Room	No. of Persons Permitted	
	Up to 3 Hours	Over 3 Hours
10 ft. by 10 ft. by 8 ft. high	7	5
15 ft. by 10 ft. by 8 ft. high	9	7
20 ft. by 15 ft. by 10 ft. high	17	13
30 ft. by 15 ft. by 12 ft. high	26	20
50 ft. by 20 ft. by 15 ft. high	55	41

Under tropical conditions and especially when relative humidity is high, the numbers will have to be reduced.

Ventilated Shelters

Collective protectors to furnish fresh air for gas-proofed shelters will be installed where practicable. The collective protector

consists of a large filter unit constructed on the same principle as a gas-mask canister and a blower. The air intake should be as far above the ground as is practicable in order to draw its air supply from an area where high concentrations of gas are not likely to accumulate. The intake should also be located so as to reduce chances of destruction by bombing. By use of the collective protector a slight positive pressure is maintained inside the shelter. This has a tendency to prevent gas entering through cracks.

The following table gives the allowance per person which must be made for varying rates of ventilation:

Period of Occupation	Shelters Above Ground		Shelters Underground	
	Total Surface Area per Person in Sq. Ft.	Ventilation per Person in Cu. Ft. per Hr.	Total Surface Area per Person in Sq. Ft.	Ventilation per Person in Cu. Ft. per Hr.
3 hours, If actively engaged	30	450	20	450
3 hours, If quiet	40	150	20	150
Indefinite	50	450	25	450

To determine the number of persons who can be accommodated in any shelter, add the surface area of the floor, ceiling, and four walls together, and divide by the minimum surface area per person shown in the table above:—e.g., Size of room—20 by 10 by 8 ft. high.

Floor and ceiling surface—twice 20 by 10	400
Two walls 10 by 8—twice 10 by 8	160
Two walls 20 by 8—twice 20 by 8	320
Total surface area	880

Thus, for a shelter above ground of this size, with a rate of ventilation per person of 450 cu. ft. per hour, 29 persons may be accommodated for three hours and 17 persons for an indefinite period.

8. Bleach Mixtures for Decontamination

Unit Coverage. In decontaminating operations, involving the use of chloride of lime mixed with earth or sand, one pound of chloride of lime is recommended per square yard of area to be decontaminated. However, in the use of bleaching powder-water mixture (slurry) this rule does not apply and the amount of bleach used per unit surface will be found below.

WEIGHT OF BLEACHING POWDER-WATER MIXTURE (SLURRY) REQUIRED FOR 1 SQUARE YARD OF TERRAIN

Kind of Surface	Weight, by Pound (Slurry)
Concrete road (smooth)	1.0
Loose surfaced macadam or gravel	2.0
Short grass (3 inches to 5 inches)	3.0
Long grass and low brush	4.0, or more

Since the bleaching powder-water mixture weighs slightly less than 11 pounds per gallon, the approximate requirements for a given area may be readily calculated.

Material Requirements Table. The following table gives the quantity of bleaching powder and water required for a mixture of equal parts by weight of the two materials. It also gives an estimate of the approximate surface area of three different types of terrain which will be covered effectively when sprayed with a given quantity of the mixture.

BLEACHING POWDER-WATER MIXTURE REQUIREMENTS FOR A GIVEN SURFACE AREA

Surface Area to Spray			Amount of Mixture Required		Materials Required		
Concrete Road	Gravel Road	Short Grass			Bleaching Powder		Water
sq. yd.	*sq. yd.*	*sq. yd.*	*gal.*	*lb.*	*drums*	*lb.*	*gal.*
640	320	210	60	640	1	320	40
1280	640	430	120	1280	2	640	80
1920	960	640	180	1920	3	960	120
2560	1280	850	240	2560	4	1280	160
3200	1600	1100	300	3200	5	1600	200

9. *Gas Casualty Kits*

a. The gas casualty kit M2 is arranged in three separate units which are adapted for man-pack in a pack unit weighing approximately 45 lbs. The kit comprises three zipper fastened canvas cases, one of which contains chemicals and individual unit tubes. The other two cases each contain three pairs of rubber gloves and three rubber aprons. The M2 kit is considered by the Medical Corps to contain sufficient medical items to treat one day's casualties in a Battalion Aid Station and the understanding is that they will be issued on that basis by the Medical Corps.

b. The case containing chemicals and individual unit tubes has the following contents:

Units	*Chemical*	*Package per Unit*
4	BAL Ointment	2 tubes
2	Eye solution M-1	6 tubes
8	Petrolatum	2 tubes
1	Amyl Salicylate	8 ounces
1	Bottle for Calamine Lotion	4 fluid ounces
1	Kit, water testing, screening	
2	Protective ointment	4 tubes
1	Fluorescein Discs	4 tubes of 25 discs
	Atropine Sulfate Discs	2 tubes of 25 discs
1	Sodium Sulamyd	
1	Copper Sulphate Solution	
4	Sulfanilamide, crystalline, USP powder	
1	Copper Sulfate powder	
2	Soap, white, floating	
4	Calamine concentrate	6 tubes
2	Eye and Nose drops	
2	Chloroform	2¼ fl. oz., 2 bottles
4	Amyl nitrite, USP	6 ampules
6	Sulfathiazole Ointment, 5%	2 tubes

Basis of Issue—1 kit per medical section (Battalion, Regimental or Squadron of the division).

Kit, First Aid, Gas Casualty (complete) contains the following:

1 Container, for Kit, first aid, gas casualty.
1 Pkg. Amyl nitrite, USP, 5 minim., amp.
1 pkg. Eye and nose drops, ½ oz., w/separate dropper.
1 set Phosphorus burn set (1-2½ oz. btl. 10% copper sulfate sol., w/1-3½ in. forceps).
1 tube Protective Ointment, CWS: 3 oz.
1 pkg. Pad, cotton, approx, 1¼ by 2 inches.
1 pkg. Eye solution, M1, ½ oz., w/separate dropper.
1 btl. Calamine Lotion NF (with phenol and menthol), 2 oz.
1 btl. Chloroform USP, 2 oz.
2 tubes BAL ointment.

10. *Chemical Warfare Service Symbols: New and Old*

Agent	*New*	*Old*
Lewisite	L	M-1
Mustard	H	HS
Mustard-Lewisite mixture	HL	MS
Brombenzylcyanide	BBC	CA
Diphenylcyanarsine	DC	CDA
Phenyldichlorarsine	PD	PDA
Arsine	SA	
Cyanogen chloride	CC	
Hydrocyanic acid	AC	
Nitrogen mustards	HN	
Ethyldichlorarsine		ED
Methyldichlorarsine		MD
Chlorpicrin		PS
Phosgene		CG
Diphosgene		DP
Chloracetophenone solution		CNS
Chloracetophenone training solution		CNB
Chloracetophenone		CN
Adamsite		DM
Diphenylchlorarsine		DA
HC Mixture		HC
Liquid smoke—Sulphur Trioxide in Chlorsulfonic Acid		FS
Titanium Tetrachloride		FM
White Phosphorus		WP
Thermate		TH
Decontaminating Agent Non-Corrosive		DANC
Incendiary Mixture (Thickened Gasoline)		IM
Incendiary-Napalm (Thickened Gasoline)		NP
Onti Lewisite Eye Ointment		BAL *

* BAL, a new ointment, is now issued troops for removing Lewisite from eyes. It is very effective, and is the most practicable first aid measure for eyes contaminated with liquid Lewisite. It is rubbed directly in eye and on lid.

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